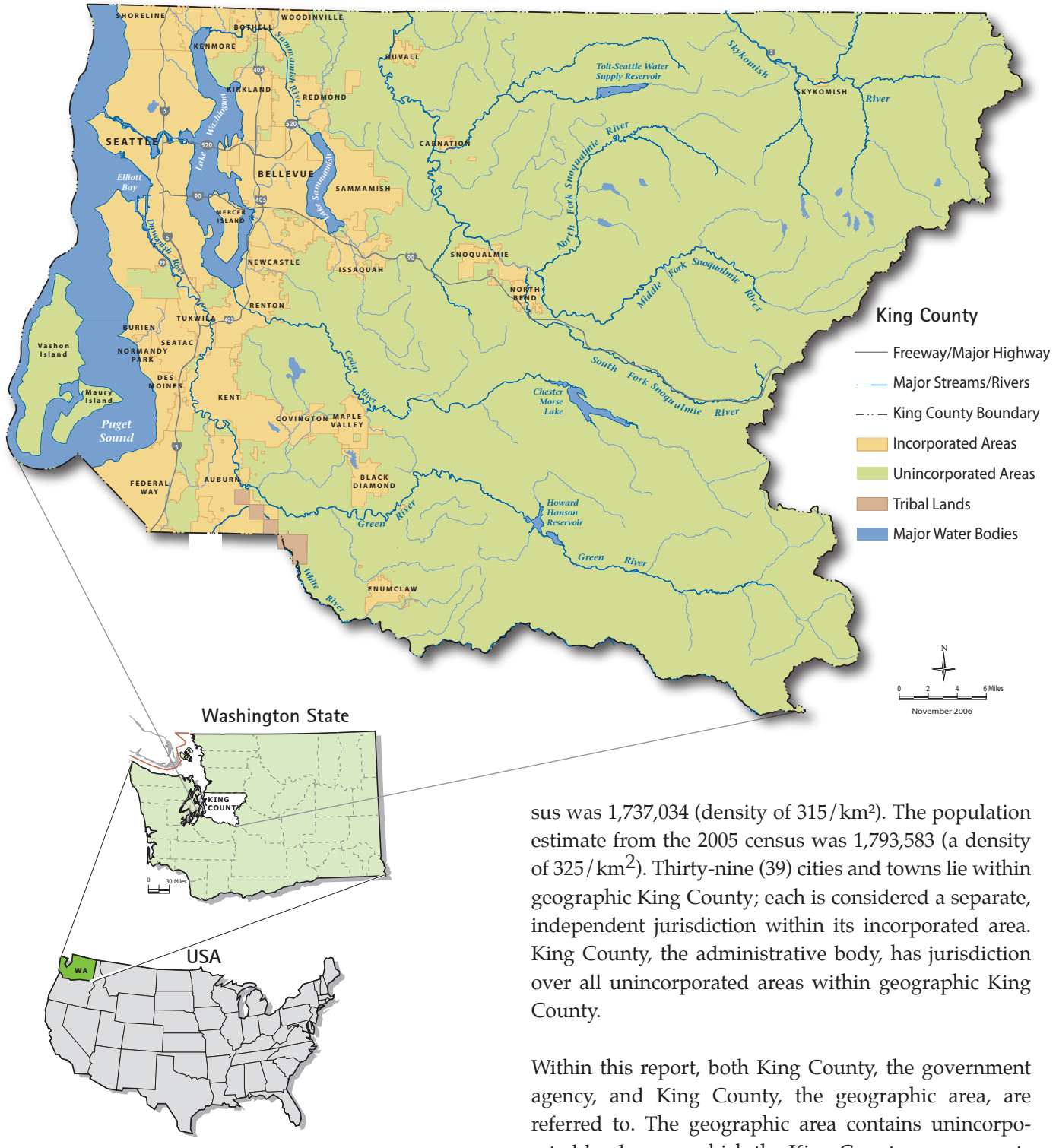
LOCALITY MAP

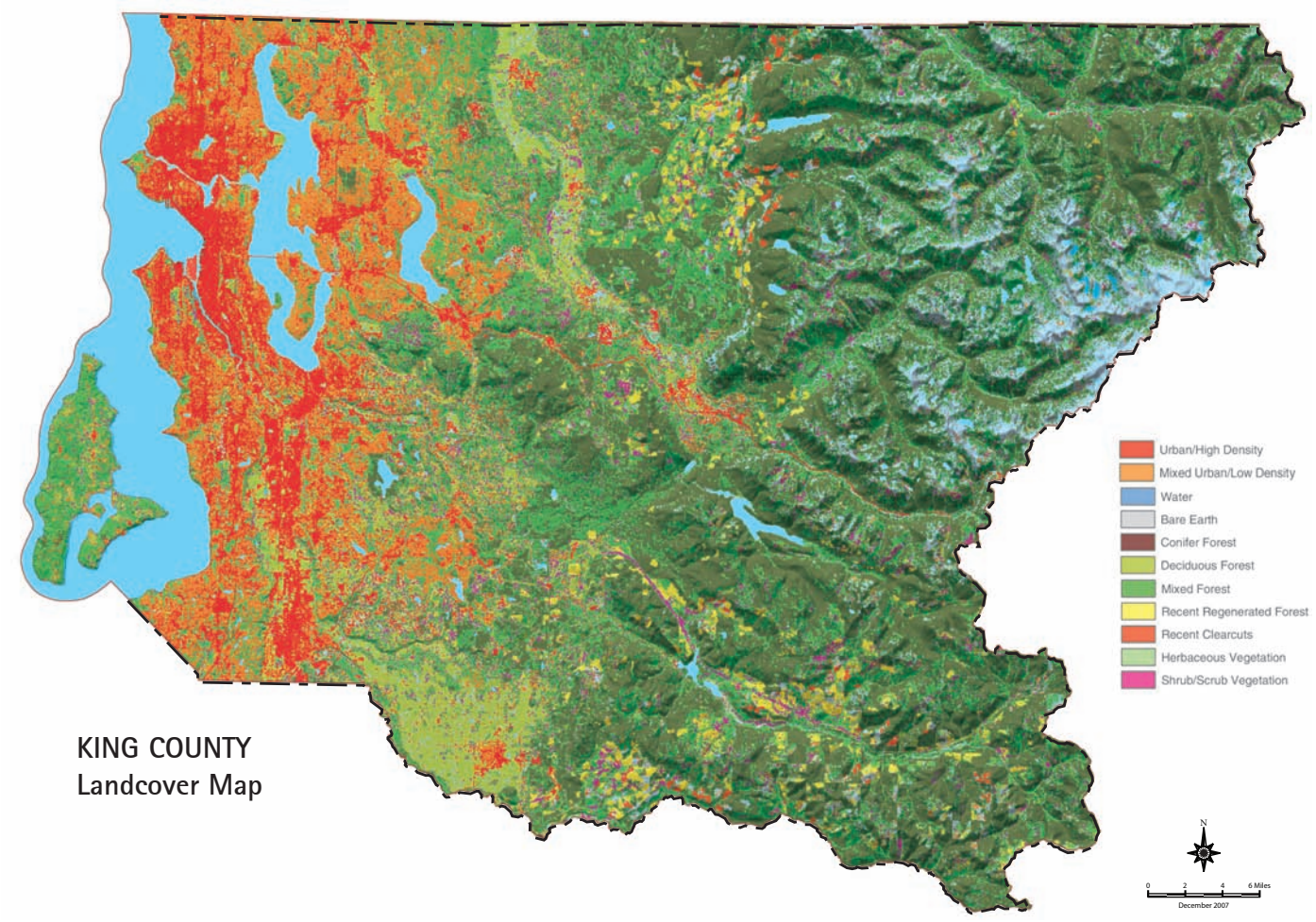


KING COUNTY, WASHINGTON

King County is located in Washington State, which is in the northwest corner of the contiguous United States. King County is 5,977 km² in size (5,443 km² land and 534 km² marine waters), and the population in the 2000 census was 1,737,034 (density of 315/km²). The population estimate from the 2005 census was 1,793,583 (a density of 325/km^2). Thirty-nine (39) cities and towns lie within geographic King County; each is considered a separate, independent jurisdiction within its incorporated area. King County, the administrative body, has jurisdiction over all unincorporated areas within geographic King County.

Within this report, both King County, the government agency, and King County, the geographic area, are referred to. The geographic area contains unincorporated lands, over which the King County governments holds jurisdiction, and incorporated areas, over which local cities hold jurisdiction. When King County, the government, is referred to in abbreviation, it is annotated with a capital C (the County), and when the land area is referred to, it is annotated with a small c (the county).

1. ECOLOGY



KING COUNTY
Landcover Map

The Ecology section describes general ecological and biological aspects of biological diversity in King County. This description is not exhaustive; it does not attempt to include all aspects of biodiversity as defined below. Rather, it is intended to introduce the reader to the variety of ecosystems, habitats, and species present within the county.

1.1 DEFINING BIODIVERSITY IN KING COUNTY

Biodiversity is defined as the variety of living organisms considered at all levels, from genetic diversity through species, to higher taxonomic levels, and includes the variety of habitats, ecosystems, and landscapes in which the species are found.

Although this definition is an ecologically and evolutionarily appropriate definition for biodiversity, it does not truly reflect King County's pragmatic approach to biodiversity. For the County, this generic definition is at once too broad and too specific to reflect the County's protection and management of biodiversity. It is too broad in so far as it includes all species found here, regardless of their status as native or exotic—the County focus is mainly on species native to the region. Moreover, the definition contains more specific levels of biodiversity for which the County has no practical goals or objectives; landscapes, ecosystems, and genetic diversity generally are not targets for rules and regulations, nor for most plans and programs (salmon recovery is a notable exception).

The County's efforts tend to focus on specific habitats and habitat types (such as streams and wetlands, for example) that have been under imminent threat from land conversion and development. In some cases, protection has focused on particular attributes or elements of habitats such as nesting trees for specific species (such as Bald Eagles) and on particular species (and their habitats) of ecological or economic interest. Species of ecological interest are threatened and endangered species and some state sensitive animal species. Species of economic interest include salmon and geoducks, which is a large bivalve mollusc. In the face of rapid land use change, and the fragmentation and habitat loss that has been a result, the County has employed a pragmatic approach to biological conservation that targets mainly the variety of habitats and species native to the County; this approach to biodiversity is both practical and workable in such a developed landscape. The approach does not rely on an explicit definition of biodiversity, however. Rather, the approach (and the implicit definition) has developed from a somewhat fragmented and serial view of conservation driven by the effects of development, first on wetland habitats, then on stream and riparian habitats, and, most recently, on wildlife habitats and listed species.

The County is attempting a more comprehensive approach to conservation beyond the eastern suburban fringe, in the uplands and foothills leading to the Cascade Mountains. In those areas, the degree of fragmentation and transformation of the landscape is much less than in the urban/suburban areas to the west, making large-scale conservation of land possible. Through large land and easement purchases, considerable areas of the foothills landscape have been set aside for conservation and to promote the continuation of "working landscapes", especially working forests. Still, the assumptions that these lands, kept in active forestry management, will provide a significant buffer for native biodiversity is untested. Even in these areas, protection is mainly afforded to particular habitat types—streams, ponds and lakes, and wetlands—within the working landscape. The role of the larger landscape in biodiversity conservation has not been evaluated. Nevertheless, King County is attempting to develop a more comprehensive perspective on biodiversity and address all levels of biodiversity suggested by the scientific definition.

Pacific ninebark, a native shrub, provides food and cover for many bird species. Photo: Jennifer Vanderhoof.

1.2 ILLUSTRATING KING COUNTY'S BIODIVERSITY

Two maps illustrating different aspects of King County's biodiversity are included as part of this report. However, depicting King County's biodiversity visually presents a challenge: on one hand so much information is available that we were forced to be selective while not misrepresenting or omitting important features; on the other hand, many features (such as certain habitat types) that we consider critical to native biodiversity are not well mapped. Because King County covers such a large geographic area (nearly 6,000 square kilometres; 2,300 square miles), two maps were created to depict the broad range of biodiversity that is found in our area. The "Landscape Diversity Map" illustrates large-scale bioregional diversity based on the US Environmental Protection Agency's Level IV ecoregion divisions. This map also includes nine special features that range from various types of protected areas to the County's wildlife habitat network. A second map, the "Rare, Threatened, and Endangered Plant and Animal Species Map," uses the same ecoregional divisions and illustrates the distribution of the known rare, threatened, and endangered species found in the county.

Landscape Diversity Map

The "Landscape Diversity" map (see pages 18 - 19) depicts the large bioregional landscapes of the County based on the USEPA Level III and IV Ecoregions (USEPA Ecoregions are the result of a nested biogeographical classification system that has been applied to all of North America. For a detailed description of the Ecoregion concept, see section 1.3). The County is divided into 9 Level IV ecoregions, nested within 3 larger Level III ecoregions. Each Level IV Ecoregion is depicted on the map by a separate color shading. Also included on this map are various federal, state, and local protected areas, management areas, preserves, and other ecologically important areas.

Publicly owned lands in King County comprise a total of 2,566 square kilometres (991 square miles), which is 46.6 percent of the total land area. These lands are owned by the federal government, the state, the County, and by cities within the county. Not all these lands contribute to biodiversity, however. For example, much of the lands owned by the U.S. Forest Service are managed for multiple use, including timber harvest. However, they also own and manage the two Wilderness Areas, which are depicted on the map. Another example of publicly owned lands not included on the map are the extensive state, County, and city park systems. A subset of these lands are included and discussed below, but most are not on the map. Many of these parks do contribute to biodiversity at some level, whereas others serve recreational purposes and contribute little (in some cases detract from) native species biodiversity.

In addition to public lands, there are 445 hectares (1,100 acres) of **privately owned land** which have been permanently protected through conservation easement purchase or donation. Another 38,000 hectares (94,000 acres) are permanently protected from development as working forests. Land trusts and conservancy organizations own additional land and conservation easements (total acres are unknown) in King County. These lands are not depicted on the map but contribute to connectivity across the county.

King County owns and manages over 10,000 hectares (24,710 acres) of **Natural Resource Lands,** including Ecological Lands (also called "Natural Areas"), multi-use lands, and parks. Only the Ecological Lands are depicted on the map, although many of the multi-use lands and parks also contribute to the county's biodiversity. The Ecological Lands are managed for their ecological value; however, they are also open to public access. Even these lands vary widely in their conservation value because of their position on the landscape, natural processes that are present, and how much they are impacted by development and human use. It is assumed that with time and active management and restoration, even those Ecological Lands that have been heavily impacted will eventually regain a natural state and contribute to the county's biodiversity.

Washington State owns or manages many parks and other natural resource lands in the county. The natural resource lands include Natural Area Preserves (NAPs) and Natural Resource Conservation Areas (NRCAs), all of which are indicated on the Landscape Diversity map. Both of the state's NAPs in King County are sphagnum bogs, which are very rare ecosystems in the region and contain rare and endangered plant and animal species. One of these two NAPs also includes a small strip of old-growth forest, which remains in King County only in relict stands. The NRCAs are managed to protect outstanding examples of native ecosystems, habitat for endangered, threatened and sensitive plants and animals, and scenic landscapes. There are three NRCAs in King County, and the most unique of these, Mount Si NRCA, contains steep, rugged and mountainous terrain. Four mountain peaks are located within its boundaries ranging from 488 to 1,463 meters (1,600 to 4,800 feet) in elevation. Mount Si NRCA supports a variety of wildlife including native mountain goats, cougar, black bear, and Peregrine falcons. This NRCA also safeguards unique geologic features, examples of old growth forests, and sensitive plant species.

Although most state parks in King County are left off the Landscape Diversity map, Federation Forest State Park is included because it is the only state park in the county that was established primarily for habitat value – in this case, the old growth forest. Similarly, the Asahel Curtis Recreation Area, part of U.S. Forest Service land, includes one of the last stands of old-growth forest in the Snoqualmie Valley region.

The Washington State Department of Fish and Wildlife (WDFW) sets aside certain areas of Puget Sound marine waters as Marine Protected Areas (MPAs) for the protection and preservation of species and habitat. There are six MPAs in King County's marine waters, and all are open to limited harvest.

Two Wilderness Areas, the Alpine Lakes and the Henry M. Jackson, are owned and managed by the federal government, in this case the U.S. Forest Service. These wilderness areas were established to protect critical watersheds and naturally functioning "pristine" ecosystems as well as allow for regulated recreation. They contain some of the most rugged landscapes in the county and are dotted with numerous high-elevation lakes.

Also included on the Landscape Diversity map are Important Bird Areas (IBAs). An Important Bird Area is a terrestrial or aquatic site identified by the Audubon Society that provides essential habitat for one or more species of birds during breeding, wintering, or migration. The sites are considered to be essential to maintaining naturally occurring populations of birds. There are two Important Bird Areas in King County: Quartermaster Harbor in Puget Sound at Vashon-Maury Island and the Cedar River Watershed, which is the City of Seattle's municipal watershed.

Quartermaster Harbor IBA provides large concentrations of forage fish for an assemblage of wintering birds and abundant shellfish for wintering sea ducks. The Quartermaster Harbor Pacific herring stock is the largest spawning population in south Puget Sound, and the third largest in the entire region. The harbor is also a major spawning area for surf smelt. Together, these two fish species form an essential component of the food chain for aquatic birds. About 35 species of aquatic birds—about 3,000 individuals annually—use this site as a wintering area.

The primary value of the Cedar River Watershed IBA is its substantial amount of relatively undisturbed low-elevation coniferous forest. It contains 5,670 hectares (12,927 acres) of old-growth forest, with some patches of trees as old as 850 years. The watershed acts as a de facto reserve, and is most significant from a conservation perspective because of the large amount of mature Western Hemlock forest. Over 100 breeding bird species are present in the watershed. The site supports an assemblage of species associated with mature coniferous forest, including Northern Goshawk, Marbled Murrelet, Northern Spotted Owl, Vaux's Swift, and Pileated Woodpecker. Breeding Peregrine Falcons have also been confirmed. Twenty-five percent of the breeding Common Loons in Washington nest in the watershed. These nesting pairs typically produce the majority of the state's fledgling loons on a yearly basis.

The Maury Island Environmental Aquatic Reserve, shown on the Landscape Diversity map, was established for the conservation of several unique ecological features, including those of Quartermaster Harbor, an Important Bird Area described above. Additionally, the reserve includes the eastern shore of Maury Island, an area that supports a unique, uninterrupted drift cell (area of mud, sand, or gravel material moved in the nearshore zone by waves and currents) that converges at Point Robinson with another drift cell along the northern shore of Maury Island. Long, relatively uninterrupted drift cells are becoming a rare occurrence in the central Puget Sound region. These physical features are critical for the maintenance and development of accretional shore features. This drift cell feeds a minimally armored sand spit found at Point Robinson, which is also an increasingly uncommon occurrence within Puget Sound. Furthermore, the reserve is unique within the central Puget Sound sub-basin because it has a diverse set of habitats and species that include extensive eelgrass beds, kelp beds, sand and mudflats, and herring, surf smelt, and sand lance spawning grounds.

The spotted owl, a federally threatened and state endangered species, makes its home in old-growth forests of the Pacific Northwest. Relatively few spotted owl pairs remain in King County; their numbers have declined significantly as old-growth forest has been removed, and this decline makes the preservation of remaining old-growth forest, such as that found on the Cedar River Watershed, even more important.

Photo: Jennifer Vanderhoof.

Natural features on the Landscape Diversity map include wetlands, rivers and large streams, and open water bodies (lakes, ponds). Outside of the marine waters, the greatest species diversity tends to be around in wetland and riparian habitats. In addition to these wetland and aquatic areas, other areas with rare or unique species would be special habitats that in Western Washington include old-growth forest, talus slopes, cliffs, and caves. Where known, old-growth forests have been included on this map. Unfortunately, no comprehensive map of the other habitat features exists for King County.

King County's Wildlife Habitat Network is also included on this map. This codified network is composed of contiguous vegetated corridors that are intended to link wildlife habitat with critical area buffers, priority habitats, trails, open space, and other areas to provide for wildlife movement, and to alleviate habitat fragmentation. County code (regulations and standards) states that the designated corridors shall maintain a width of 90 meters (300 feet) to the maximum extent practicable and not to be less than 45 meters (150 feet) at any point.

Rare, Threatened, and Endangered Plant and Animal Species Map

The map entitled "Rare, Threatened, and Endangered Animal and Plant Species" (see pages 24 - 25) includes all Federal and State listed threatened and endangered animal species known to be currently or historically regularly present and breeding in King County. Table 1 summarizes the species included on this map. Rare animal species included on this map were chosen because they meet two criteria: (1) they depend on habitat types that are representative of rare or threatened habitats in the county, and (2) some spatial data in natural (not man-made) habitats are known about them. King County's Critical Areas Ordinance (see Section 2.2) establishes protection for the nesting/breeding locations of a longer list of species, many of which potentially or possibly face decline because of loss of unique habitat features or habitat types. However, a lack of spatial data makes mapping those species impossible. Despite the absence of certain rare animal species from this map, we believe that, especially when used in combination with the Landscape Diversity map, it paints a picture of those areas and habitats in King County that are critical for the survival of our rarest and most threatened species.

Rare plant species that are tracked by the Washington Natural Heritage Program are also included on this map. Twenty-six rare plant species that are tracked occur historically or presently in King County. Ten of these species are historical records, and the remainder are represented on the map. These 26 rare plant species in King County that are tracked by Washington Natural Heritage Program (WNHP) mostly depend on habitat types that are declining in quality or abundance in both the county as well as regionally. The majority of these rare species are found in wetlands (often sphagnum bogs) as well as along stream and lake edges. Nine of these 26 species are wetland obligates, meaning they are found almost always in wetlands. An additional 4 of the species are called "facultative wetland plants," meaning they usually occur in wetlands. Therefore, half of the rare plants tracked by WNHP are wetland species, and many of these have hydrologic alterations (as a result of land development) as their greatest threat.

Because fire is now suppressed in King County (and most places inhabited by people in the United States), our native lowland prairies and grasslands have nearly disappeared from the county. Three rare plant species (Golden Paintbrush [*Castilleja levisecta*], White Meconella [*Meconella oregano*], and White-top Aster [*Sericocarpus rigidus*]) that depend on grassland habitat have as their greatest threat invasion by either Douglas-fir or by non-native shrubby species. If fires still burned naturally, these shrubs and trees would not be able to grow and proliferate, and the grassland species, which evolved with fire regimes, would potentially still be present. Of these three species, two (Golden Paintbrush, White Meconella) may be extirpated from the county.

Three rare animal species are not included on this map because the only spatial data known for their breeding locations are in man-made structures: Townsend's big-eared bat, Purple Martin, and Vaux's Swift. Townsend's big-eared bat is a Federal species of Concern and State Candidate whose greatest threat is disturbance by humans of nursery colonies or hibernating colonies in caves and mines as well as vandalism. An additional

Table 1. Animal Species Included on Map of "Rare, Threatened, and Endangered Plant and Animal Species."

Map Element	Reasons for Decline or Rare Status	Presence in King County	State and Federal Status*	Explanation of Map Data**
MAMMALS				
Fisher	Hunting, historically. Currently, lack of undisturbed, late-successional forest with rotting logs and cavities	Presumed extirpated.	FCo, SE	GAP data, based on 1991 landcover: "habitat in core zones."
Grizzly Bear	Livestock depredation control, habitat deterioration, commercial trapping, unregulated hunting, and the perception that grizzlies threaten human life.	Extirpated. Most recent observation was single animal in 1989.	FT, SE	
Gray Wolf	Intensive human settlement, loss of habitat, conflicts with domestic livestock, lack of understanding of the wolf's ecology and habits, and superstition.	Populations extirpated; occasional individuals may wander in. Two mapped observations from1992 and 2003.	FE, SE	
Wolverine	Historic fur trapping, degraded habitat through timber harvesting, ski area construction, road construction, and general human disturbance.	Two observations, dated 1983 and 2005, both near eastern county line at elevations over 4000 ft.	FCo, SC	
Killer Whale (Orca)	Large historic declines in their main prey, salmon; heavy contamination with organochlorine pollutants, primarily PCBs and DDT residues; and whale watching activities. Past capture for aquarium display.	Use Puget Sound, including King County's waters.	FE, SE	All marine waters of King County are potential feeding and overwintering habitat.
BIRDS				
Bald Eagle	Previously, eggshell thinning by DDT in mid-twentieth century. Current problems include loss of shoreline habitat, disturbance by humans, biocide contamination, and decreasing food supply.	Nesting habitat may be saturated around Puget Sound, including King County. Sound-wide, carrying capacity is estimated at about 770 nests.	FCo, ST	PHS data: nests observed 1978 - 2006.
Marbled Murrelet	Loss of old-growth forest to forestry practices.	Unknown number of pairs breeding in remnant old-growth stands. Presumed extremely rare in King County.	FT, ST	PHS data: All observations shown, not just nests, dated 1993 - 2005. Only 1 - 2 nests are known currently.
Spotted Owl	Loss of old-growth forest to forestry practices, combined with habitat fragmentation by large highways and being out-competed by more aggressive Barred Owls.	Unknown number of pairs breeding in remnant old-growth and mature forest stands.	FT, SE	PHS data: Observations of observed pairs only, 1983 - 1999.
Peregrine Falcon	Historically, nearly extirpated because of DDT. They are currently increasing in population.	Nests are either in Seattle on man-made structures or in NRCAs (see Landscape Diversity Map).	FCo, SS	PHS data: nests observed 1994 - 2005.

Map Element	Reasons for Decline or Rare Status	Presence in King County	State and Federal Status*	Explanation of Map Data**
Common Loon	Shoreline alteration and development, fluctuation of water levels during nesting (e.g., reservoir draw downs and filling), human disturbance in the vicinity of nesting areas (boat traffic), and encroachment by logging and road building.	Nests on water-supply reservoirs and a few small lakes, all with limited public access (no recreational boating or residential development). Some nests are on man-made floating structures.	SS	PHS data: nests observed 1984 - 2003.
Northern Goshawk	Loss of habitat to development and short-rotation timber operations.	All known nests in eastern half of county, all in Forest Production District.	FCo, SC	PHS data: nests observed 1990 - 2000.
REPTILES AND AMPHIBIANS				
Western Pond Turtle	Loss of nesting sites to development and non-native vegetation, predation by domestic pets, roadkill, damming, diverting, and polluting of waterways. Fragmentation of landscape has caused loss of access to upland nesting sites near aquatic habitat.	Presumed extirpated.	FCo, SE	PHS data, 3 individual observations, 1988 - 1992.
Tailed Frog	Increasing temperatures and sedimentation of many of the cold, clear mountain streams they require, as a result of logging, road building and other construction practices.	Present in cold, higher-elevation streams in the eastern third of King County.	FCo, SM	PHS data 1989 - 1998.
Larch Mountain Salamander	Loss of old growth forests and young naturally regenerated forests with remnant old growth features (such as large woody debris). Alteration or loss of talus slope habitats, including from logging, which changes microclimate and resources of talus slopes, and mining of talus for road construction.	Only a few remnant populations are still in King County: one in southeast King County and two other isolated populations in the vicinity of Snoqualmie Pass.	FCo, SS	PHS data from 1997 - 1998 surveys on private and Federal timberland.
FISH				
Chinook Salmon	Habitat degradation, hatchery influences, and over-harvesting.	Wild fish present in historic watersheds, but in reduced extent and population size. In some instances, continued supplanting of hatchery fish, numbers may meet or exceed historic wild populations.	FT, SC	Distribution data compiled by regional staff.
Bull Trout	Habitat degradation and over-harvesting.	Present in reduced numbers in all historic watersheds and Puget Sound. Populations may be increasing in some watersheds, but still not at historic levels.	FT, SC	Distribution data compiled by regional staff.
Steelhead	Habitat degradation, hatchery influences, over-harvesting, and unfavorable ocean conditions	Wild fish present in historic watersheds, but in reduced extent and population size. Reduced life-history diversity in all watersheds. In some instances, the production of hatchery fish has increased numbers to meet or exceed historic wild populations.	FT	Steelhead listed as Federally threatened in May 2007; data not yet added to map.

Map Element	Reasons for Decline or Rare Status	Presence in King County	State and Federal Status*	Explanation of Map Data**
INVERTEBRATES				
Beller's Ground Beetle	Loss of sphagnum bogs to logging and development. Climate change may present a future threat if bogs dry up.	Present in isolated sphagnum bogs; five observed occurrences in King County.	FCo, SC	PHS data for 3 points (1979, 1985); King County Bog Inventory data for 2 points (1997, 1998).

* FE: Federal Endangered; FT: Federal Threatened; FC: Federal Candidate; FCo: Federal Species of Concern; SE: State Endangered; ST: State Threatened; SC: State Candidate; SS: State Sensitive; SM: State Monitor.

** "GAP" is Washington Gap Analysis Program; "PHS" is Washington Department of Fish and Wildlife Priority Habitats and Species program.

threat is blockage of cave/mine entrances through collapse or human activities. Surveys have not been conducted in the county's mines or caves, and the only mapped locations of nursery colonies are in old barns or houses. Purple Martins would no longer be present in King County or most of the region were it not for nesting gourds placed along marine and lake shorelines. This species is now wholly dependent on human intervention for its survival in King County. Vaux's Swift is a bird whose natural nesting habitat is hollow old-growth trees. They occasionally use chimneys as well. They are a State Candidate species, and their numbers are reduced from pre-logging days as a direct result of loss of old-growth habitat. Currently the Breeding Bird Atlas reports them as probably nesting in scattered locations across King County, though the only confirmed, mapped sites are chimneys.

The Oregon Spotted Frog, a State Endangered and Federal Candidate species, is presumed extirpated from the county and is therefore not included on the map. This species has declined throughout is range primarily from effects of development (changes in water temperatures, water levels, and cover; polluted run-off), as well as the introduction of invasive species such as American bullfrogs, which are very difficult to eradicate once established. The Oregon spotted frog is the most aquatic of our native frog species. It prefers year-round shallow, slow moving waters with abundant emergent vegetation and a thick layer of dead and decaying vegetation on the bottom with water levels that do not fluctuate during breeding season. Because of these habitat preferences, their chances of naturally re-establishing healthy populations in King County are not high.

The western toad, a State Candidate species and Federal Species of Concern, is not included on the map because of a lack of spatial data. The Washington Herp Atlas shows records of the species in five scattered locations across the county between 1984 and 2004. They use a variety of habitats, including forested areas. Breeding waters are usually permanent and include wetlands, ponds, lakes, reservoir coves and the still-water off-channel habitats of rivers. This species has experienced rapid population declines in Washington, including King County, and the reasons for the decline are unclear.

The Pileated Woodpecker, a State Candidate species, is not included on the map because spatial data for them is incomplete. They are confirmed nesters in scattered locations throughout the county. These birds prefer mature and old-growth forests for nesting although they can be found in younger mixed forests where hardwood snags are present. Pileated woodpeckers may be considered "ecological engineers" because they are the only species able to excavate large cavities in hard snags and decadent live trees, and a wide array of other bird and mammals species use their cavities.

Bald Eagle, a most regal bird and our national symbol, nests along many shorelines of King County. Photo: Jennifer Vanderhoof.

For these reasons, they are also considered a keystone species.

Stellar sea lions were listed as threatened under the Endangered Species Act in 1990, but no critical habitat has been identified in King County or Puget Sound. Because they are only occasional visitors to our waters and they do not breed here, they are not included on the map.

The pygmy whitefish is a State Sensitive species that spawns in cold fast-flowing mountain streams that flow into cool lakes, where they rear. Their only population in King County is in the Cedar River above Chester Morse Lake. Too little is known about this population to know how it is doing relative to pre-logging conditions. However, the vast majority of this watershed, which was historically logged, will no longer be logged, and as forest conditions mature, it is assumed the stream conditions will remain the same or improve, and likely the same will be true for pygmy whitefish.

The Olympic mudminnow is a State Sensitive species that is most often found in wetlands. King County is out of its range; however, this species has been documented in certain wetland ponds in the county, but it is thought that the presence of these individuals is the result of intentional introductions of the fish, and not because of a natural range extension.

Snags provide important habitat for woodpeckers. This snag has been heavily used by a pileated woodpecker, a species of concern in King County. Photo: Jennifer Vanderhoof.

1.3 DESCRIBING THE BIODIVERSITY OF KING COUNTY

In this section, we describe the social and geographical context, general condition, and attributes of biodiversity in King County based on the definition found in section 1.1. This section includes a general history of settlement in King County, an estimation of the general health of biodiversity in the county, and a narrative that describes the diversity of landscapes (ecoregions), habitats, and species of the county. This narrative is not exhaustive: it does not include all species or habitats found in the county, nor does it provide a description of population or genetic diversity of the plants and animals found here—little is known about these levels of biodiversity in this region. We have attempted to touch upon as many aspects of native biodiversity as we have reliable information for; the level of detail varies across attributes. Nevertheless, this section provides a useful and illuminating view of the sweep of biodiversity across the county and should serve as a point of departure for further investigations into the variety of King County's ecosystems and their inhabitants.

The Context for Biodiversity in King County

Since the 1850s, Seattle and King County have grown from scattered settlements to an estimated population of 1.8 million people. Most of this growth has occurred in the lowlands between the shores of Puget Sound and the foothills of the Cascade Mountains. Today, King County encompasses an urban/suburban area that stretches from the Sound to the Cascade foothills 40 kilometers (25 miles) to the east. The western Cascade slopes and foothills remain in timber production, mainly on private forest land, and two of the three major river valleys are mainly agricultural. Alpine areas are largely in roadless or wilderness designations and are off limits to any development.

Over the last 150 years, the Euro-American inhabitants of King County have dramatically altered much of the landscape within the county's boundaries. Although the Puget Sound region has been inhabited for several thousands of years, it had been visited by Europeans intermittently since about the mid-16th Century (Juan de Fuca), and explored by Vancouver in the late 1790s. Euro-American settlers arrived in King County in the

early 1850s with settlements at Alki Point and Seattle. Timber harvests then began in earnest (an 1840 estimate had put the forest resources of Washington at some 578 *billion* board feet (1.8 billion meters) and had attracted much interest from eastern timber companies. Perhaps half of that was timber in Puget Sound); the first sawmills were operating by 1853. By 1900, the Puget Lowland (including King County) and the lowland river valleys were being logged rapidly. One observer noted that the lands surrounding Puget Sound had been stripped of forests for at least 3.2 kilometres (2 miles) inland from the shore and for nearly 11 kilometers (7 miles) up the major river valleys by 1880. The Green River valley of King County was one of the first lowland valleys to be cut over using the new techniques of clear-cutting and patch cutting; the lower and middle valley for 48 kilometers (30 miles) had been almost completely cut by 1920.

The 1920s saw an overall decline in the local forest products industry as national markets grew smaller in post-war years and timber reserves were being depleted. Many mills in Seattle, on Lake Washington, and in the Snoqualmie, Sammamish, and Cedar River Valleys were bankrupt, passed into the hands of receivers and completely disappeared, along with a number of the communities that depended on the mills for payrolls. In King County the industry had been in serious decline ever since the end of World War I.

Following a depression in the 1890s, the area was revitalized by the Klondike gold rush just before the turn of the 20th Century as Seattle became the hub for prospectors heading north and for some who struck it rich on their way back from the Yukon. King County was gaining in population quite rapidly during this time, its population rising from 110,000 in 1900 to over 284,000 by 1910. Even as the importance of the timber industry in King County declined, agriculture was gaining prominence and King County farms, many located in the fertile valley of the Green River, were a mainstay of Washington State's farm production. In fact, one area located in the lower Green Valley was known as the "lettuce capital of the world" in the 1920s and 1930s. In King County at least, the Great Depression of 1929 did not have so dramatic effect on the rural areas.

Western toad, a species of concern in King County, is a highly terrestrial amphibian; this one was spotted far upland of its breeding habitat. Photo: Jennifer Vanderhoof.

The end of WW II saw a second wave of immigration to King County, and this time land development accelerated in the uplands to the east of Seattle (the suburbs). Once again, lumber mills in the area had geared up for production during the war, and post-war suburban growth helped keep production going into the 1950s, but decline was inevitable, and only a few mills remained in King County by the 1970s. The Snoqualmie mill, one of the last facilities in the region capable of cutting large timbers, was closed in 1989.

Largely because of the pressures of an expanding population and the pace of land development, the preservation of open space and farmlands in King County became an issue in the 1970s. In 1979, voters overwhelmingly approved the King County Farmlands Preservation Bond issue. Under this program, the first purchase of farmland development rights by the County took place in January 1984. Over US$ 50 million in development rights were purchased at that time. That effort has been followed by other programs that preserve open space for parks and recreation and for ecological purposes. In 1989 King County voters approved a major open space bond issue that provided funds for the purchase of recreation and resource lands around King County. Additional monies since then have added to the growing public ownership of parklands, open spaces, wildlife habitats, and other resource lands. Among the public-private partnerships created to preserve the quality of life in the region was the Mountains to Sound Greenway Trust, which is working to coordinate the preservation of scenic, cultural, natural, and economic resources along the Interstate 90 corridor from the Cascade Mountains to Puget Sound. Again in the late 1990s, an acquisition program focused on ripar-

Clearcuts are not an uncommon sight in the Forest Production District. Photo: Jennifer Vanderhoof.

ian lands, the Waterways Program, added to the growing inventory of ecological lands in public ownership. King County continues to acquire several hundred acres of ecological lands per year, using salmon recovery funding, conservation futures, and a variety of other funding sources. To date, the County inventory of ecological lands exceeds 2,428 hectares (6,000 acres).

General Health/Condition of King County's Biodiversity

Because the time that has elapsed since Euro-American settlement has been relatively short, and because adjacent counties have not urbanized as quickly, certain elements of King County's biodiversity have not suffered as dramatically as might be expected from the density and extent of observable landscape change within the populated areas of the county. Nevertheless, some attributes of landscape and habitat biodiversity have been grossly altered, probably irretrievably, and other attributes that are dependent on these landscapes are showing signs of decline. In general, biodiversity in King County can be characterized as moderately healthy, with both signs of further habitat and species declines as well as signs of potential recovery for other habitats and species. Although this is a decidedly mixed outlook, much of the damage to our landscapes and habitats may lie in the past, and there is cause for optimism as we strive to protect our remaining natural areas and retrieve some of the most imperilled species from the brink of extinction in King County.

King County's Ecoregions

In keeping with the definition of biodiversity used by King County, we have organized the discussion by dividing the county into marine, freshwater, and terrestrial landscapes using the USEPA Ecoregional scheme for the Pacific Northwest. Within each general ecoregional landscape, ecosystem types and habitats are noted and discussed separately. Within the marine landscape, for example, backshore, intertidal and shallow subtidal, deep subtidal, and riverine/sub-estuarine ecosystems are discussed; within the freshwater landscapes, wetland ecosystems, lake ecosystems, and river and stream ecosystems, are described; and within the terrestrial environment, lowlands, foothills and uplands, and alpine landscapes are described.

Ecoregions provide a useful framework and background for the discussion of marine, freshwater, and terrestrial environs of the county. The discussion of ecoregions is based on U.S. Environmental Protection Agency (EPA) ecoregion conventions, which result in units similar to European biogeographical regions because they denote areas of general similarity in ecosystems.

EPA's ecoregions have been mapped across the North American continent and are classified hierarchically into four levels of increasing complexity and detail. There are only 15 Level I ecoregions across the entire continent, and King County falls within 2 of these: Marine West Coast Forests and Northwestern Forested Mountains. There are 52 Level II ecoregions, and the two that occur across King County correspond identically with the Level I ecoregions: Marine West Coast Forest and Western Cordillera. Level III regions describe smaller ecological areas nested within level II regions. There are three Level III ecoregions in King County: Puget Lowlands, Cascades, and North Cascades. Level IV ecoregions describe an even finer scale of nested ecological areas and allow locally defining characteristics to be identified and more specific management strategies to be formulated for such local conditions. In King County, there are nine Level IV Ecoregions (see Table 2 and Landscape Diversity Map).

Each of King County's Level IV ecoregions is discussed below in Level III groupings. Afterwards, we will specifically discuss the marine, terrestrial, and freshwater landscapes found in King County.

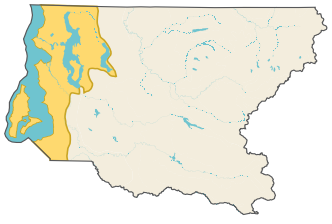
Table 2. Level III and Level IV Ecoregions That Lie Within King County's Geographic Boundaries.

LEVEL III	LEVEL IV
Puget Lowland	Eastern Puget Riverine Lowlands
	Eastern Puget Uplands
	Central Puget Lowland
North Cascades	North Cascades Lowland Forests
	North Cascades Highland Forests
	North Cascades Subalpine/Alpine
Cascades	Western Cascades Lowlands and Valleys
	Western Cascades Montane Highlands
	Cascade Subalpine/Alpine

The Puget Lowland Ecoregion

The Puget Lowland Ecoregion of King County, including its component Central Puget Lowland ecoregion, Eastern Puget Riverine Lowland ecoregion, and Eastern Puget Upland ecoregion, have undergone perhaps the greatest change since settlement, and this landscape is where biodiversity has declined the most. These ecoregions were the first to be logged, the first to be turned to agriculture, and have borne the brunt of encroaching settlement and urbanization. In the lowlands of King County, from the shores of Puget Sound to the uplands and foothills of the Cascades, the once-continuous forests of Western hemlock, Western Redcedar, and Douglas-fir have largely been replaced with forest plantations, farms and fields, cities, towns, and their suburbs. The remains of this ancient and great forest, where trees grew to 70 meters (230 feet) tall, 2 meters (6.6 feet) in diameter, and over 800 years old, are now found only in small, scattered reserves or in remnant groves, mostly in the foothills, and mostly in state or federal ownership. The scale of this loss is illustrated by the presence of two small "pioneer" groves within the City of Seattle, the only remaining lowland examples of this formerly dominant landscape in King County.

Central Puget Lowland



Based on 2002 landcover data, approximately 710 square kilometres (274 square miles) of urban area lie in the county, and nearly all of it is in the Puget Lowlands. This entire Central Puget (CP) Lowland ecoregion, approximately 933 square kilometers (333 square miles), is now dominated by urban and suburban uses, criss-crossed by roads, and fragmented into patches of residential, commercial, and industrial uses. Little area has been spared the pressure of development. Few areas remain undeveloped along the mainland shoreline of King County; Elliott Bay, for example, is the main harbour and industrial area for Seattle. Virtually all the remaining undeveloped marine shoreline in King County occurs on Vashon Island, approximately 4.5 kilometers (2.5 miles) offshore from the mainland. Yet even this area has no completely undisturbed shoreline remaining. Lake Washington and Lake Sammamish, King County's two largest lakes, lie within the CP lowlands; each has an extensively developed shoreline, and little native habitat remains intact amid retaining walls, bulkheads, docks, and lawns to the water's edge. Even the lake levels have been adjusted downward as a result of canal construction and river diversions in 1906 and more recent adjudication of water levels to prevent residential flooding.

Protection of biodiversity in King County occurs mainly at the habitat level through the use of restrictive regulations and covenants within recent developments. Wetland and stream protection regulations specify buffers and setbacks for these "critical areas" from development activities and finished infrastructure; nesting trees and breeding sites of certain species of animals are also protected through regulation. Even as these

Much of Vashon Island's shoreline has been extensively altered. Docks are overwater structures that can have a major impact on shoreline processes and wildlife.

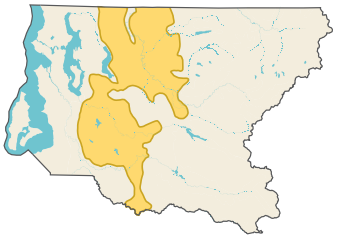
buffers have increased in width and breeding areas are protected, the greater landscape continues to fragment. The County has attempted to conserve animal populations against this fragmentation by connecting existing habitats using a codified Wildlife Habitat Network and by recognizing habitat "complexes" (currently only for wetland systems). However, until very recently, the use of landscape planning tools such as "SmartGrowth" (the densifying of existing population centers in an attempt to reduce urban sprawl), the transfer of development rights from outlying lands to urban areas, and the outright purchase of land or development rights in forest areas has not been directed expressly at preserving biodiversity. As a result, large-scale, landscape ecosystem biodiversity, as represented in the ecoregion discussion, has declined more dramatically than either habitat or species biodiversity, and many habitats, especially wetland, stream, and forest habitats, have been compromised by the effects of land use in the surrounding landscape. Few, if any, complete native landscapes remain in this lowland ecoregion.

Eastern Puget Riverine Lowland

The major river valleys of King County within the Eastern Puget Riverine Lowland ecoregion have undergone similar changes to the Central Puget Lowland ecoregion. This ecoregion comprises only about 291 square kilometres (112 square miles) in King County but contains a wide variety of aquatic and terrestrial habitats and ecotones, and a rich complex of animal and plant communities. The rivers and streams of this ecoregion were, and still remain, the major spawning and rearing areas for the seven native species of Pacific Salmon and trout, and two species of char that occur in King County. Of this group, three species (Chinook salmon, steelhead and bull trout, a char) have been listed recently under the U.S. Endangered Species Act and are the subject of region-wide recovery efforts. Although these three species have been the first listed, virtually all the salmon, trout, and char species (with the possible exception of Pink salmon) of King County have declined in abundance and distribution over the last 100 years and the potential exists for further listings. More factors are at work in the salmon declines than landscape change and habitat degradation, however. Over-harvest and the overuse of hatchery programs have eroded genetic and life history diversity and migration barriers have reduced the distribution of salmon. The recovery programs for Chinook salmon address all these factors and progress is steady in changing past management regimes.

Among the first area to be logged and turned to agriculture, this ecoregion would also be unrecognizable to the first explorers or to the 18th Century Native American inhabitants of King County. These valleys were once heavily forested by flood tolerant species such as western redcedar, black cottonwood and Sitka spruce; the largest trees in the county occurred in these fertile lowland valleys. By about 1890, the valleys of the Green River and the lower Snoqualmie River had been extensively logged and converted to agriculture, which remains the dominant land use for the Snoqualmie. The lower Green has seen considerable urbanization with residential and commercial land uses replacing the agricultural areas over the past 25 years. With human land use eventually came a desire for protection from the regular floods that swept these rivers. A major flood control dam was completed on the Green River in 1963, and the lower river has an extensive levee system. In the Snoqualmie, agricultural use required only the construction of revetments and a few levees but no major dam. Nevertheless, the floodplains in both systems have been grossly modified for crops and pastures, and the sloughs and oxbows, side channels and backwaters, along with the extensive riparian forests were mostly lost by 1950.

Eastern Puget Uplands



The Eastern Puget Uplands, the area of moraine and rolling foothills up to about 823 meters (2,700 feet) above sea level (ASL), encompasses approximately 1,307 square kilometers (467 square miles) and is considered an ecological transition zone from the Puget lowlands to the forests on the western slope of the Cas-

cade Mountains. This ecoregion should also be considered a transition zone for land use as well because the intensity of settlement declines from west to east across the ecoregion. From its western edge, newly created cities and their suburbs gradually give way to farming areas, woodlots and forests, a few small towns and, finally, to the current forest production zone on the highlands and in the rising foothills. This area remains prominent in the production of forest products and includes extensive private forest lands, two state forests, and the western edge of federal forest lands. Working in concert with local conservation groups, it is in this area that much of the County's land acquisition and protection is directed. This attention is both timely and warranted as expanding local cities begin to include farmland within their growth boundaries and forest companies dispose of extensive forest holdings along the foothills. This area is probably experiencing the pressure of an expanding King County population more than any other ecoregion.

In the eastern reaches of this ecoregion many habitats and species can be found that were once common and even abundant throughout the lowlands to the west. Large wetland systems, nestled in morainal troughs or in the depressions of ancient kettle lakes, dot the landscape and small lakes and ponds can be found throughout. Plant and animal species have either retreated to these areas as the landscape has been developed or are survivors of the past alterations of the landscape. Herds of elk, once common in the lower river valleys and across the highlands have been pushed into the foothills and forests of the west slope; bobcats are encountered less and less in the interspersed forests and woodlands that remain. Black bear and cougar, now sharing their foothill habitats with more people, are seen in backyards and along trails (see Mammals discussion below).

Like the Puget Lowland, the Eastern Puget Uplands have been altered considerably from their past condition. Although little irreversible change has occurred here, the landscape bears little resemblance to that first encountered by settlers. Mostly unbroken forest covered the land; these forests are similar to the lowlands, with the addition of a few tree species that were at the lower limit of their elevation range and a rare few that were holdovers from the glacial past. Douglas-fir, western redcedar, and some white pine were present in the lowlands, and these species transitioned to a mix with some silver fir and noble fir upslope. Truly a transition zone, this area was probably rich in species and in complex forest habitats that differed because of slope exposure, soils, and fire history. A few remnants of the original forest are scattered throughout the eastern edge of this ecoregion. However, the forests that are present today are much less diverse in species, age, and size, which are characteristics of the vertical and horizontal complexity of mature stands.

The North Cascades Ecoregion

From the Puget Ecoregion, we move upslope into the North Cascades Ecoregion and its three component Level IV ecoregions: North Cascade Lowland Forests, North Cascade Highland Forests, and the North Cascades Subalpine/Alpine. Together, these ecoregions comprise approximately 1,838 square kilometers (656 square miles) and extend from about 244 meters (800 feet) ASL in the river bottoms to over 2,134 meters (7,000 feet) at the Cascade crest.

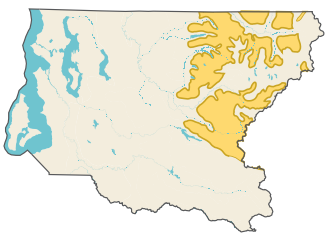
North Cascade Lowland Forests

The North Cascade Lowland Forests are the lowest (in elevation) extension of the Cascade Ecoregion and encompass the upslope valleys of King County's major river systems: the Skykomish River Valley in the northeast, the Tolt River Valley in the north, and the three forks of the Snoqualmie (North, Middle, and South) in eastern King County. Of these, the Skykomish forests penetrate farthest to the east, approaching within a few miles of the Cascade Crest. These are deeply cut valleys for the most part, and it is possible to traverse from the river bottom to subalpine heights on a single slope. In doing so, one would walk from lush forests of the river bottom through several plant communities in a relatively short horizontal distance. In the river bottoms, the lowland forests of western hemlock, western redcedar, and Douglas-fir were historically dominant—large trees with dense canopies that kept the river bottoms cool and moist. These forests were the focus of much logging

in the late 19th and early 20th centuries and had been mostly logged off by the end of WWI. As logging operations ceased in these valleys, the lands were left to regenerate. These forests grow quickly in the valley bottoms but the new stands are little like the old and complex forests that once stood here. Still, the new forests are gaining in age and structure as they are left to regrow or are newly managed for ecological benefits as well as commodity value.

It is in this ecoregion that the relationship among forests, rivers, and Pacific Salmon reaches a zenith. The often closed canopy of the bottomland forests maintains a tunnel of cool air above the river, and the canopy helps keep waters cool; leaf and needle-fall are building materials for aquatic insects (some of which are dependent on the needles of particular species of conifer for their cases; one particular species of caddisfly has declined, for example, because the needles of Sitka Spruce are now in short supply). Aquatic insects are important food for young salmon. Trees that fall in rivers via windthrow and riverbank erosion provide cover, create complex habitats, and trap the gravels necessary for salmon spawning. In fact, in these rivers, this large woody debris (as it has come to be called) is a critical component of healthy salmon habitat. Much of the wood that finds its way to lower rivers and on into our coastal estuaries originates in this ecoregion and is delivered by floods to the lower reaches. The three forks of the Snoqualmie, however, lie above Snoqualmie Falls which is an impassable barrier to up-migrating Pacific salmon. These rivers still play an important role in moving nutrients, wood, and gravel into the lower mainstem river where salmon reside. Despite the history of logging, this ecoregion remains largely forested with regenerated stands and is slowly regaining basic ecological functions important to riparian and aquatic biodiversity.

North Cascade Highland Forests



The North Cascades Highland Forest Ecoregion lies between 854 meters (2,800 feet) ASL and approximately 1700 meters (5,600 feet) and covers approximately 874 square kilometers (312 square miles); ownership is dominated by the US Forest Service (the Mt. Baker-Snoqualmie National Forest), although there is considerable private land at the lower elevations of this ecoregion. This ecoregion is the heart of the Pacific Silver Fir (PSF) zone, and the namesake species may occur in almost monotypical stands at mid-elevations. In the upper reaches of this zone, Pacific Silver Fir often blends with Alaskan cedar, mountain hemlock, and even subalpine fir. This terrain is often the steepest and, coupled with deep snowfall, makes for severe snowpack instability on some western slopes. These areas are known as avalanche tracks and are easily seen as long, vertical strips of shrubs and other non-tree vegetation. The consistent and violent disturbance of avalanches has produced a distinct vegetation community that contrasts with the adjacent forests. In the place of large conifers, dense thickets of shrub-like mountain alder, vine maple, and mountain maple, with flexible and bowed stems, dominate many of the tracks. But not all tracks have proven to be the same; the composition of the vegetation communities, though all shrubby and flexible to avalanche surges, tends to be related to the frequency of the avalanche disturbance: the greater the frequency of disturbance, the fewer conifers and the more mountain alder and other low shrubs. This pattern makes for considerable diversity amid the forest stands and the tracks are feeding grounds for a variety of subalpine and highland animals.

This ecoregion was one of the last remaining timber-producing areas within King County until the late 1970s. Finally, in 1989, the last mill capable of cutting old-growth size logs was closed. With the growth of population in the lowlands to the west, the forest has lately become a major recreational destination. Forest production from this area is now mainly confined to private lands although some harvest occurs on state and federal lands. What remains of the forest outside the wilderness and roadless areas is mainly a forest with little structural diversity mostly of the same species and age in stands less than 50 to 75 years old.

North Cascades Subalpine/Alpine

The North Cascade Subalpine and Alpine Ecoregion extends from about 854 meters (2,800 feet) ASL to almost 2,400 meters (7,900 feet) ASL at Mt. Daniel, the highest point in King County. The dramatic landscapes of the North Cascade subalpine/alpine ecoregion of King County cover 452 square kilometres (161 square miles) and are the work of continental and alpine glaciers. This area comprises the least disturbed landscapes in the County. However, human influence and effect is present here too: old mining claims, most now abandoned or unworked, dot the alpine landscape, and the area is used heavily for recreation by the citizens of King County and Puget Sound. Most of the subalpine and alpine landscape is contained within two wilderness areas: the Alpine Lakes Wilderness in east central King County and the Henry M. Jackson Wilderness in the far northeast corner of the county. The Alpine Lakes Wilderness is a landscape of small mountain lakes nestled among the high rock peaks and timbered valleys of the region. Approximately 500 of these small lakes are found in King County. Over half of Washington State's population lives within a one-hour drive of the Wilderness. With nearly 150,000 visitors each year, the wilderness areas have suffered considerable damage in all accessible areas.

The Subalpine Ecoregion is dominated by mountain hemlock, which extends from the Pacific Silver Fir-dominated zone to timberline, occasionally intermixed with Alaskan Cedar and scattered Pacific Silver Fir, and often set amid open subalpine meadows or "alpine parkland." Heavy snowpack at this elevation often persists into mid to late-summer and suppresses the growth of trees except in a few scattered locations. These meadows come to be dominated by a mix of heathers (not true Old World heathers but related), mountain huckleberry, and sedges at higher elevations. These meadows often bear the brunt of heavy use by hikers. The steady use of informal trails through heather meadows degrades and eventually destroys plant cover. The ribbon of trail cuts deeper into the soil and is further aided by erosive forces of wind and snowmelt until the track is shin-deep. When the trails reach that point, they are often abandoned for a parallel track and the process begins again. Restoration of these meadows has become a constant activity of the Forest Service in recent years and many areas have been closed to foot traffic until the area is healed, a process that takes many years.

An alert visitor to these meadows and parklands will see a variety of animals, some residents of the subalpine and others that travel from lower elevations to graze or hunt during the spring and summer. Among the more charismatic animals are elk, black-tail deer, black bear, and cougar; rarely seen, except by their tracks or other sign, are grey wolves and Grizzly bears, two species that are making a return to the Cascades after being eradicated earlier in the century (see Mammals discussion below). Two avian species, both faithful indicators of this ecoregion, are Clark's nutcracker and the gray jay. Ruffed grouse are common but rarely seen in the brushy areas, and goshawk and golden eagles hunt over the meadows. Year-round residents of this ecoregion are rare because of the harsh winters, but one in particular typifies the close fit between habitat and inhabitant: the marmot is the most recognizable animal that is regularly encountered in this region. Both the hoary and the yellow-bellied marmot can be found throughout the North Cascades.

The summit of the Cascade rim is only a few hundred feet above these meadows and parklands, and the boundary between subalpine and true alpine, the timberline, is often characterized by the presence of dwarfed conifers or *krummholz*, much as in the Alps and other mountain ranges of the world. Heather meadows can be expected in the wetter areas of these stony slopes, along with patches of black sedge, mountain heliotrope, and Alaskan spirea. On the uppermost alpine ridges, the terrain is stony (called fellfields in other parts of the world), plant cover is sparse, and only a few species find footholds in this extreme habitat: sandworts, fleabanes, wild buckwheat, and saxifrages are the most conspicuous plants. Little has changed in this landscape since the large alpine glaciers departed from these ridges and slopes.

The Cascades Ecoregion

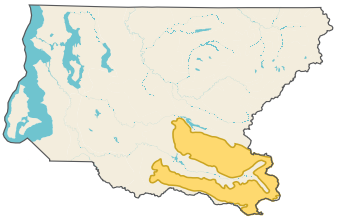
To the south of Interstate 90, the Cascade Mountains take on some characteristics quite distinct from the northern portion of the range. These southern mountains are bedded mainly on volcanic rocks rather than the granitics that typify much of the northern North Cascades Region. Peaks along the crest are not so high, only reaching into the truly alpine at Blowout Mountain (1,732 meters; 5,680 feet) at the very eastern extreme of the upper Green River watershed. In King County, the Cascade Ecoregion includes the Western Cascade Lowlands and Valleys, the Western Cascades Montane Highlands, and the very limited Western Cascades Subalpine/Alpine.

Western Cascade Lowlands and Valleys

In King County, the Western Cascade Lowlands and Valleys ecoregion encompasses 666 square kilometers (238 square miles) and is dominated by three river systems: the Cedar River, which penetrates along the northern edge of the Cascade region; the Green River in the central portion; and the White River, which marks the boundary between King County and Pierce County to the south. The ecoregion also extends to the northeast for approximately 25 kilometers (15 miles), along a broad, glacial meltwater-formed valley that penetrates the Puget Uplands. This valley links the Puget Lowlands to the Cascade Highlands. According to certain historical accounts, this "thumb" was a major corridor for both human and animal travelers between the two regions. Because of their proximity to Seattle and other settled areas of Central Puget Sound, these valleys were among the first to be logged and the first to be converted to agriculture in their lower reaches; logging and agriculture continue here today. In the Duwamish-Green River Valley, for example, the first Euro-American settlers arrived in 1851; by 1853 a steam-powered sawmill was operating at the mouth of the Duwamish-Green river at Elliott Bay and by 1880, logging had extended into the upper watershed, some 97 kilometers (60 miles) from the bay.

Between about 1910 and the end of WW I, the lower elevations of this ecoregion were cut almost completely and converted to agriculture. Flood control levees and revetments along the three major rivers aided this conversion. In 1948, the Mud Mountain Dam was completed on the White River. This was soon followed by Howard Hanson Dam on the Green in 1963. With the damaging floods controlled on these rivers, industry began to push aside agriculture in the lower valleys. Today, the ecoregion remains primarily in forestry production compatible with the use of the major rivers as water supplies for the metropolitan area. In fact, virtually all of the ecoregion within the Cedar River Watershed is managed to assure the quality of Seattle's water supply. *A Habitat Conservation Plan developed for the 36,600 hectare (90,500 acres) watershed in 2002 has an objective to "Eliminate timber harvest for commercial purposes to effectively create a watershed ecological reserve"* and management is now focused on regaining the old forest structure. (The City of Seattle has committed to stop commercial logging in their 36,600-hectare (90,500-acre) municipal watershed). Even so, little of the native forest landscape remains, even in this protected area. The only other large old-growth stands occur in Federation Forest State Park in the upper White River Watershed. Despite these changes, cougar, black bear, elk and deer are all common residents of this ecoregion, even at its lowest elevations.

Western Cascades Montane Highlands



The Western Cascade Montane Highlands (612 square kilometers; 219 square miles) are also dominated by timber harvest. Most of the lands in this ecoregion are in private ownership, except for the Cedar River Watershed and the Tacoma Watershed lands. A patchwork of clearcuts and reforested areas characterizes this landscape, and all but the steepest and most inaccessible areas are traversed by forest roads. This fragmentation has produced a forest cover that is predominantly in early to mid seral stages (less than 75 years old); less than 10 percent of the ecoregion is in a late seral stage (old growth). Many of the existing late seral forest

stands tend to be located in riparian areas of headwater streams or areas on very steep slopes. Much of the riparian corridor was harvested during the original timber harvest in the 1880s or burned in fires at the turn of the century. Currently, riparian vegetation along the mainstem rivers (with the exception of the Cedar, where the riparian zone is being managed for large mature conifers) is predominantly small to medium-sized deciduous or mixed deciduous and coniferous stands. These vegetation communities are in sharp contrast to the size of the pre-harvest trees that once lined the streambanks. This patchwork of forest harvest has almost certainly altered the distribution and abundance of many forest dwelling birds and mammals. Although few historic records exist, the use of pre-logging forests by a variety of species, some now rare, has been suggested by a number of researchers. Among the species using these mid-elevation forests is the spotted owl, now listed under the U.S. Endangered Species Act.

Western Cascades Subalpine/Alpine

The Western Cascades Subalpine/Alpine ecoregion occupies only about 2.5 square kilometers (1 square mile) in King County, mostly on the slopes of Blowout Mountain (at 1,732 meters, 5,680 feet ASL). This area differs little from the subalpine areas of the North Cascades in vegetation and animal species. This small area of King County lies on the Pacific Crest Trail, the main north-south recreational trail along the crest of the Cascade Range.

Terrestrial Habitats

The terrestrial habitats of King County include distinctive land-based vegetation communities found in the lowlands, highlands, and sub-alpine and alpine areas of the County. Although some of these habitat types are relatively undisturbed (especially in subalpine and alpine areas), many are the result of human induced changes in the landscape over the last one and a half centuries. The discussion that follows is, by necessity, quite general but highlights the salient characteristics of habitats found in rural, urban/suburban, and undeveloped areas of the County.

Lowlands and Foothills

The history of land use in King County has produced a lowland and foothill landscape of bewildering variety. The once continuous forest of western hemlock, Douglas-fir, and redcedar has given way to a patchwork of lawns, parks, playgrounds, woodlots, greenbelts, old fields, croplands, tree farms, and remnant forests set amid a landscape of urban, suburban, rural, and commercial uses, all joined and, at the same time, separated by a vast network of roads and communication corridors. Despite this apparent richness and variety of patches, this landscape is clearly human-dominated, and habitats for native species have generally been marginalized by the scale and pace of land conversion and resource extraction. This pattern is not, of course, unusual in the history of development. Even so, over the last 30 years, King County has made significant strides in protecting and preserving a variety of habitat types that are critical components of biodiversity. We will discuss the following terrestrial habitat types: forests and woodlands; greenbelts, parks, and corridors; meadows, old fields, hedgerows, and shelterbelts; and riparian habitats.

Very little old-growth forest remains in King County. This stand is in a small park in a West Seattle neighborhood. Photo: Robert Fuerstenberg.

Forests and Woodlots

The large forest blocks within King County lie mainly in the foothills where logging is still the dominant land use; some of these lands are in private hands, some in state ownership, and some in County ownership. Virtually all these lands have been harvested at least once, and the forests tend to

be dominated by early to mid-successional stands of conifers, under 70 years old—many under 50. The few exceptions lie in small blocks of a few hundred acres at most and include two small stands (each less that 11 hectares, 25 acres) of old growth forest in the City of Seattle, Federation State Forest, a 215-hectare (490-acre) grove of old growth in the White River valley of southeastern King County, 3 - 4 remnant stands in the Green River Valley, and a stand in the Mt. Si Natural Resource Conservation Area (see Landscape Diversity map). Most estimates put the total extent of virgin (uncut) old-growth lowland forest in King County at less than about 10 percent of the historic amount. Except for some "pioneer stands", none of this forest occurs at elevations below 305 meters (1,000 feet). The best known examples of this historic forest are indicated by the tree symbols on the biodiversity map.

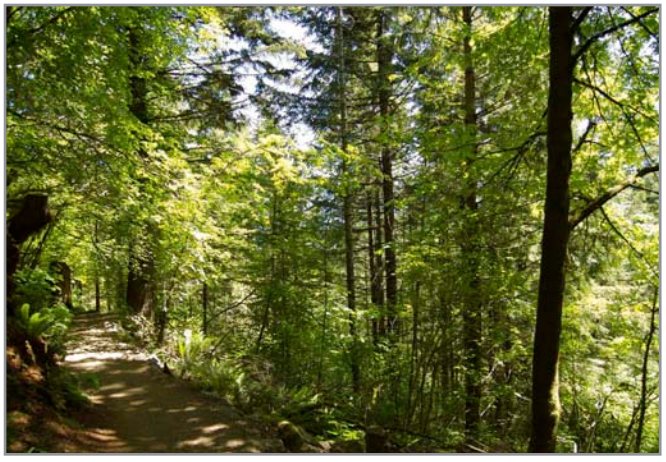
Forest management has taken a decidedly ecological turn in the last two decades and local public forest lands have begun to show the effects of this enlightened technique. Tiger Mountain State Forest in central King County and City of Seattle's Municipal Cedar River Watershed have worked diligently with local forest ecologists to shape their management toward recovering old growth structure in their forests. The results have been encouraging: the forest are showing multiple layers of vegetation, a lush ground cover of mosses and ferns, greater diversity in age classes, and greater species diversity faster than expected. King County is attempting the same sort of management on its working forest lands and awaits the results in 20 to 30 years.

These forests are exceptions to the general rule, however, and the most stands still harvested for commercial purposes are patch and block cuts where regaining ecologically sound forest structure is not an objective. These forests tend to be composed of many even-aged blocks with very high stem densities that are periodically thinned over the life of the stand. The harvest cycle may be as short as 35 years or as long as 70 in some cases; these forests tend to be almost monotypical where one or two species dominate the forest, and the forest floor may be almost devoid of a groundstory. Forest edges are sharp and abrupt, patch size is small, and deep forest microclimates are largely absent. Animal diversity in these forests, especially avian diversity, is much lower than in the ecologically managed stands discussed above.

Adjacent to the agricultural areas of the county, forests tend to be a mix of conifer and deciduous trees, remnants of more extensive stands that have been left to regenerate on their own. Most of these stands are small woodlot patches of a few 10s of acres (at most) that border fields or surround wetlands, or have regrown after fields were abandoned. Red alder, a pioneer species in cutover lands, and Douglas-fir dominate these forest patches, and the understory may be almost entirely composed of Himalayan blackberry, a non-native member of the genus *Rubus* that was brought to the Pacific Northwest with the first settlers. On the wetter lands of the valley bottoms, small stands of black cottonwood dot the floodplains amid the fields. Many of these stands are regrowth that followed the first wave of clearing, but a few stands in the Snoqualmie valley are probably the progeny of the original trees and have attained girths approaching 1.2 meters (4 feet). These stands and other scattered along our major rivers provide important resting stations for neotropical migrant birds on their way to the northern boreal forests to breed.

Closer to the urban fringe, many forest blocks lie within or surround residential subdivisions and are the remains of former tree farms converted to urban uses. Some of these forest stands are required to remain intact by County development codes and are termed "open space" tracts. These woodlands are kept in protective status in perpetuity, presumably managed by the associations that are established by the residents of the subdivision. More often, these early successional, mixed stands are neglected and are overtaken by invasive species, many of which escape from the landscaping of the development. In addition, most open space forests associated with subdivisions are relatively small, isolated from adjacent tracts by roads, and penetrated by both formal and informal trails that allow recreational use by local residents (but not by the wider public).

Greenbelts, Parks, and Corridors



Red alder, a deciduous species, often grows in disturbed areas such as along roadsides.

Despite the scale of development in the urban and suburban areas, visitors to King County invariably remark on the number of trees that occur in the developed areas of the county. Once again, many of the remaining stands are in greenbelts, urban separators, riparian buffers, and open space parks. These areas have been set aside by city and County codes or occur on steep slopes, or were enshrined in parks earlier in the century. Nevertheless, these habitats are common and regular features of the urban/suburban landscape. Some of these vegetated features are remnants of stands planted by the farmers who were lately resident here and reflect species preferred by them or by conservation agents seeking to protect soil and water. Other stands are the remains of orchards or woodlots; still others were planted by the first urban dwellers some 30 years ago and are large and old enough that their origins are lost on the new residents. Some greenbelts and corridors protect steep slopes on hillsides or in ravines and have a wild look about them—these open spaces still retain many of the native species that once dominated the area, but they are also home to escapes such as English ivy and holly. Whatever their origins, those who live near these green spaces are highly protective of them, and many citizens have taken it upon themselves to laboriously remove the non-native invaders from these spaces.

There are a few notable parks in this area that appear to be centers of high species diversity amid the urban landscape, at least for birds and small mammals. Cougar Mountain Regional Wildland Park, a King County-owned area, lies at the very edge of the urban area and is a kind of outpost of the Western Cascade Lowland Ecoregion. Almost 1,360 hectares (3,100 acres) in size, it is by far the largest park in the County system and comprises conifer stands, deciduous ravines and riparian areas, and mixed forest habitats. It is the first in a series of foothills that align from west to east into the Cascade Highlands. Next in line to the east is Squak Mountain State Natural Area, further east is West Tiger Mountain Natural Resource Conservation Area, and finally the Rattlesnake Mountain Scenic Area. This extensive corridor seems to provide a pathway for avian species to and from the highlands and gives Cougar Mountain a higher than expected richness of birds. This unanticipated richness suggests that Cougar Mountain may be a kind of biodiversity "hotspot" in the lowland landscape of King County.

Meadows, Old Fields, Hedgerows, and Shelterbelts

Agriculture is a dominant land use in the river valleys of King County.

Set amid the farmlands of King County that still occupy the Snoqualmie valley, the middle Green Valley, the White River valley, and the Enumclaw Plateau are many habitats that are artifacts of the agricultural use of this land, both past and present. Some resemble habitats long altered—the meadows and old fields of the Enumclaw area in south King County are a facsimile of the unusual prairie habitats that dotted this upland in 1850. Others are the remains of land management activities from a bygone era—the aging shelterbelts and windbreaks of blue spruce, eastern juniper, Lombardy poplar, and white pine that still line a few farmsteads

or stand along lanes. Some—hedgerows—are accidents of marking fields with rough-cut posts that sprouted branches or are neglected fencerows of Nootka rose and elderberry. Many of these anthropogenic habitats have probably become substitutes for the native types that have been lost.

In the river valleys, along the wet bottomlands, row-crops gave way to pastureland for dairies that has, in turn, given way to abandoned fields. Some of these fields have reverted to shallow ponds and swampy meadows, with clumps of willow and red-osier dogwood on the margins. These habitats are stopovers for waterfowl and also harbor amphibians, prey for frequently seen Great Blue Herons. These wetlands are also the haunts of water shrews and meadow voles, and the Northern Harriers that hunt them. But they are also the habitats of many exotic species: nutria, Virginia opossum, and American bullfrogs, to name a few. Other, somewhat drier fields have become meadows dotted with shrubby pioneers such as elderberry and black hawthorn, or invading Scot's broom. These habitats provide food and cover for ground-nesting birds, including Savannah Sparrows.

Along the drier upland meadows and abandoned fields, Red-tailed Hawks can be seen perched on fence posts, telephone poles, and trees hunting for the abundant mice and voles that make these oldfields home. These abandoned fields are often overgrown with non-native thistles, and American Goldfinches can be seen flitting from patch to patch.

Shelterbelts, also called windbreaks, can attract a diversity of birds, especially if they are the only trees for some distance. In the open lands of the Enumclaw plateau, for example, windbreaks and the occasional woodlot account for considerable bird diversity and are important nesting sites in the agricultural landscape.

Hedgerows and fencerows, though small, provide food, shelter, and habitat to many species that use these "edge" habitats and give some measure of structural diversity to otherwise monotonous fields and pastures. Other habitats of these areas include field borders, roadsides (if they are left unsprayed), and the occasional abandoned stock pond.

Subalpine and Alpine Areas

Alpine lakes are jewels in the mountains of King County, and many, such as Snow Lake (pictured here), are hiking destinations. Photo: Jennifer Vanderhoof.

Except for a very small area in the SE corner of the County, the subalpine and alpine habitats are located in the North Cascades Ecoregion that occupies the NE quarter of King County. This ecoregion is composed of steeply dissected valleys that rise precipitously to the subalpine (montane) forests, meadows, and parklands and, in a short distance more, to the alpine ridges and peaks of the Cascade Crest. The habitats that typify this high-elevation zone are among the most undisturbed habitats remaining in King County.

For the purposes of this discussion, we separate the subalpine zone into three distinctive habitats: the montane forest, the subalpine parkland, and the subalpine meadow. The montane forest zone is characteristically an unbroken forest of mountain hemlock with isolated trees of Alaska cedar and Pacific Silver fir; however, on the western slopes of King County's mountains, the forests with Pacific Silver fir typically transitions directly into the subalpine parkland without passing through a hemlock forest. The Montane forest is the coolest and wettest of the forested zones in the Pacific Northwest. Annual precipitation is 163 to 284 centimeters (64 to 112 inches); snowfall is heavy (406 to 1,270 centimeters; 160 to 500 inches), with a snowpack up to 6.4 meters (21 feet) deep that persists into late summer. The dominant species, mountain hemlock, is a large tree for this elevation (1677 meters, 5,500 feet, and higher). It matures to 500 - 700 years of age and can be 38 meters (125 feet) tall and up to 2 meters (80 inches) in diameter. Understory plants in these hemlock forests will include

mountain huckleberry, mountain rhododendron, and bear grass (which is actually in the lily family). Bear grass is a tall plant with a spectacular creamy white bloom, which supports communities of insects in the spring. Typical animals of the montane zone are elk, black bear, cougar, and deer, all of which migrate here in summer for food and to breed and descend in winter to avoid snowpack.

At the upper elevational limit of the montane zone, mountain hemlock forest gives way to the parkland zone, a habitat of shrub-herb meadows dotted with isolated patches of trees. In King County, this parkland habitat dominates the landscape just west of the mountain crest from Snoqualmie Pass all the way to Snohomish County to the north (continuing all the way to Canada). Southward, this habitat type does not appear again until Mt. Rainier. Many ecologists familiar with the mountains of the world contend that this parkland habitat is unique on the planet, both for its extent and for its deep (gradual) transition between forest and open meadow. The shrub-herb layer of this habitat is mainly a blend of three species of New World heathers and a dwarf shrub, mountain huckleberry; the tree islands generally consist of three conifers: mountain hemlock, subalpine fir, and Alaska cedar. Notably, this habitat is far from static and may even be somewhat transient, an accident of recent climatic history. In the early 1900s, subalpine fir and mountain hemlock began to invade the meadows, reaching a peak in the 1930s before dying back. Most alpine ecologists believe that a warmer, drier period from about the 1880s through the early 1930s promoted the invasion. Now, only scattered saplings, bleached and wind-worn, remain to remind us of this dramatic advance and retreat of vegetation. This invasion could occur again with warming trends attributable to climate change, and it may persist for far longer than the 40 - 50 years of the last invasion.

At slightly higher elevations, especially on the windward faces of this zone, even the small islands of trees are no match for the conditions, and the open meadow zone dominates the slopes. Again, heathers and mountain huckleberry may be the dominant ground cover, but in spring some meadows bloom with glacier lily (*Erythronium grandiflorum*[1]), avalanche lily (*E. montanum*), and springbeauty. Later in the summer, these same meadows boast white pasqueflower, mountain artemesias, alpine bistorts, and paintbrush. In the persistent snowy places of these meadows, the black alpine sedge forms tenuous communities that appear and disappear from year to year. Among the boulders and talus slopes of these meadows are the dens of yellow-bellied and hoary marmots, mammals and the only full time residents of this habitat.

Above the timberline that marks the upper limit of the subalpine zone lies the alpine zone of the Cascades, a habitat of such severity that no trees can persist. The line that demarcates subalpine from alpine is often populated by *krummholz,* the species-nonspecific name for the dwarfed conifers that sprawl along the ground in the direction of the prevailing winds. In King County, the alpine zone is characterized by many low-growing herbs that extend upward from the subalpine zone: Alaska spirea (*Luetkea pectinata*), mountain heliotrope (*Valeriana sitchensis*), and the black sedge (*Carex nigricans*) are common. A few other shrubby species also may be found here: common juniper, shrubby cinquefoil, kinnikinnik, and snow willow (*Salix nivalis*). This last species, with its prostrate growth habit, is often a surprise in the alpine and its remarkable growth habit is more characteristic of willows commonly found in the far north. Nevertheless, this habit is not merely a growth variation within a species; snow willow is truly distinct species. In general, the species that characterize the alpine habitat of King County tend to be shared with the upper limits of the subalpine.

Mountain goats are a fairly common mammal found in alpine areas.
Photo: Jennifer Vanderhoof.

1. Scientific names are used when common names may cause confusion or misidentification.

Aquatic Habitats

The aquatic habitats of King County include a variety of wetland types, large and small lakes, rivers and streams together with their riparian areas, and habitats of the marine waters of the County. The detail within each section below generally reflects the availability of information about each habitat type. For example, whereas much is known about County wetlands and rivers, less information is available about alpine lakes and marine habitats.

Wetland Biodiversity in King County

Wetlands are recognized as critical ecosystems for biodiversity because of their disproportional use by wildlife and exceptional habitats for plants. It is their unique combination of shallow aquatic habitats and adjacent terrestrial conditions extending over a wide range of geomorphic and elevational settings that accounts for their ecological complexity and resultant richness. Because of their landscape setting, each wetland tends to exhibit unique habitat types and characteristic arrays of species adapted to idiosyncratic conditions, products of each wetland's ecological and evolutionary history.

Types of Wetlands

Because of its size (6,000 square kilometers), variety of landforms, and diverse landscapes (marine to alpine), King County includes a large diversity of marine, estuarine, riverine, lacustrine and palustrine wetlands. Although not all wetlands have been discovered, the lowland portions of the county have been surveyed, first in 1983, and again in 1990, for the presence of wetlands and their hydrologic, vegetation and wildlife characteristics. Little similar work has been done for the foothill and alpine landscapes, however, and many wetlands remain undiscovered. In the most recent County wetland survey (1990), some 884 wetlands were surveyed and mapped in the unincorporated areas of King County alone (unincorporated areas are those parts of the county not within cities or towns and not in Federal ownership). These wetlands comprise approximately 8,800 hectares (20,000 acres) and are of several general types, listed in the table below.

Table 3. Types of Wetlands in King County, Including Quantity and Area.

Wetland system	Number of wetlands	Hectares (Acres)
Palustrine	836	5,507 (12, 556)
Lacustrine	18	419 (956)
Palustrine/lacustrine	17	473 (1,078)
Estuarine	13	1,074 (2,449)
Marine	~30	~132 (~ 300)
Total	884	8,789 (20,039)

Palustrine wetlands are also called *emergent* wetlands. Water is shallow and plants, mainly herbaceous, but including shrubs and some trees, grow up through the water. The following are types of palustrine wetlands:

- **Forested wetland:** A forest floor of saturated, mucky soil. Trees found here might include alder, Sitka spruce, Oregon ash, and cottonwoods.
- **Shrub/scrub wetland:** Water saturated soil covered by dense shrubbery such as dogwood, crabapple, salmonberry, and hardhack.
- **Bogs and peatlands:** A thick mat of sphagnum moss encircling or covering a small lake or pond containing cranberry, Labrador tea, and bog laurel. Bogs were formed after glacial retreat in pothole lakes; many have been around almost 10,000 years.
- **Wet meadow:** Areas that often look like soggy pastures of grasses, rushes, and sedges.
- **Marsh:** The classic, and most familiar, wetland type; shallow mix of open water and vegetation that includes cattails, pond lilies, sedges and rushes, and many other types of plant life. Marshes that occur along the marine coastline are salt marshes.

The most common type of wetland recorded in the inventory is the palustrine shrub-scrub type. This type is well-distributed throughout the urbanized lowlands of the county and may owe its current abundance to historical beaver activity and manipulations of these wetlands for agriculture. Forest practices, mining, and the effects of land development activities increased sediment and nutrient delivery to these shallow areas and sped the invasion of shrubby vegetation. These wetlands tend to be dominated by two or three shrub species, one of which—hardhack, or Spirea—can form

dense, almost impenetrable stands throughout the wetland. These wetlands may also have a ring of willow or red alder surrounding the wetland center.

In our few, relatively undisturbed scrub-shrub wetlands, we find a greater richness of shrubs and small trees, even some areas of shallow, open water that provide habitat for herbaceous species, amphibians, birds and small mammals. American beaver are often present (see mammal discussion for how the American beaver significantly contributes to wetland complexity and biodiversity). In these wetlands, we may encounter typical small tree and shrub species including cascara, vine maple, crabapple, Oregon ash, red-osier dogwood, and devil's club. Herbaceous species include veronica, watercress, smartweed, marsh speedwell, water parsley, skunk cabbage, and lady fern.

Our most unique and sensitive palustrine wetland type is the bog or peatland. Of the total number of wetlands in lowland King County, 80 have been identified as bogs or peatlands. This type generally owes its existence to the retreat of glacial ice from the Puget lowland some 10,000 to 12,000 years ago when blocks of ice broke from the glaciers and formed small kettle lakes in the recently revealed landscape. The combination of cool conditions, local hydrology, and acidic and organic soils, favored the growth of sphagnum mosses along the edges of these lakes. The sphagnum moss adds to the acidic conditions, further creating an environment that favors other low pH tolerant plants. A typical, well-developed bog in King County will have hummocks of sphagnum with wild cranberry and sundew growing in close association with Labrador tea, bog laurel and possibly a few stands of cotton grass. Older bogs also contain western hemlock and remnant western white pine, which is especially rare in King County. Many, if not most, of the peatlands identified in lowland King County have been substantially altered by peat mining and agriculture over the past 150 years. Of the lowland peatlands, King's Lake Bog (a state natural area), Queens Bog, Hylebos Bog, Laughing Jacobs Lake Bog, and the Paradise Lake Bog are our best examples of bogs.

Lacustrine wetlands are those associated with the littoral zones (the shallow) edges of lakes and ponds. These wetlands also have emergent vegetation such as bulrushes (*Scirpus* sp.). Riverine wetlands occur along the edges of rivers and streams, in sloughs and backwaters, and in abandoned bends and oxbows. Estuarine wetlands occur at the interface of marine waters with freshwaters, usually at river mouths, and have plant species adapted to periodic immersion by both freshwater and saltwater. Marine wetlands include saltwater-fringing marshes and backshore wetlands. These wetlands typically have species adapted to the high salinities of marine and brackish waters. Many possess cellular mechanisms to rid their tissues of salt (such as saltgrass and pickleweed). Estuarine and marine wetlands are both discussed further in the Marine Habitats section.

Open-water and bog wetlands are not as common as they were historically, as many have been filled for agriculture or other forms of development. Photo: Jo Wilhelm.

Plant and Animal Diversity in King County Wetlands

During the County wetland inventories, observations were made of plants and animals encountered by the field crews. Although not all of these plants or animals are exclusive to wetland habitats, all have some association with these habitats during their life history, and a few are, in fact, found only in wetlands.

Eighteen tree species, both conifers and deciduous, were recorded from wetlands. Of these, the most common are red alder, willow, and black cottonwood. The rarest trees were lodgepole (shore) pine, western white pine and paper birch. Few invasive trees were noted in the inventory although it has been suggested that red alder now occupies more wetland area than it did before

Labrador tea grows in boggy areas . Bogs are rare habitats in King County, and plant assemblages that grow in bogs are found nowhere else. Photo: Jennifer Vanderhoof.

Euro-American settlement. Lodgepole pine and paper birch were found only in a handful of wetlands and may be relicts of a cooler northwest.

Forty-two species of shrubs were noted, the most common of which are Douglas spirea, willow species, and salmonberry. The least common include three species of huckleberry (found mainly in peatlands), devil's club, and cascara. Of these, cascara bark was often harvested for its laxative benefits and may help explain the species' present rarity. Several non-native species show up on the list, most notably evergreen blackberry and Himalayan blackberry, two of the most widespread invasives in all types of King County habitats.

Herbs accounted for 161 species observed but almost a third of these are non-native invasives. The invaders causing the most concern are reed canarygrass in wet meadows and shrub-scrub wetlands, purple loosestrife in shallow marshes, yellow iris along sluggish stream, pond, and lake margins, Eurasian water milfoil in lakes, and sargassum, Japanese eelgrass and Spartina in marine wetlands. Even some once-uncommon native plants have become somewhat invasive, especially in the disturbed landscapes of lowland King County. Cattail is one such aggressive species that has spread broadly in the disturbed landscape of urban King County.

Over 100 species of birds were observed in wetlands during the inventory and, because the inventory was confined to the lowland region of the county, mid- and high-elevation species would undoubtedly increase this total when considering all wetlands. Ducks and geese accounted for 30 species, wading birds (herons and egrets) for 9 species, coots and grebes for 6 species, shorebirds for 5 species, with perching birds, raptors and seabirds making up most of the remaining species. Among the more common and easily observed birds of King County wetlands are mallards, coots, Canada geese (many flocks, which are now year-round residents), red-winged blackbirds, great blue herons, and dark-eyed juncos; among the least common and unusual are loons (mostly winter salt-water visitors), wood ducks, American bittern, Virginia rail, green-backed herons, and black-crowned night herons, black brant, and western grebes. This last species was once far more common in our winter estuarine waters. A few non-native bird species have been recorded from wetlands as well but do not seem to pose as great a threat to native biodiversity as invasive plants. Brown-headed cowbirds, European Starlings and House Sparrows, all widespread species, were commonly observed during the inventory. For more discussion of bird species, see the Wildlife section.

Thirty-five species of mammals have been recorded in King County wetlands: 14 species of rodents, 12 species of carnivores, 7 species of insectivores, and 2 species of herbivores. The most unexpected was the observation of a single masked shrew in 1988. This species is mainly distributed in the boreal forests far to the north of King County. Other rare species noted include beaver (once very common), muskrat, river otter, mountain lion (in an area of the foothills), and long tailed voles. Most common observations include deer mouse (most common), Trowbridge's shrew, creeping vole, and raccoon.

Fourteen species of amphibians have been recorded using King County wetlands. Although the richness of native amphibians is not great, wetlands in King County are used by a wide variety of amphibians. Western toads, Pacific treefrogs, Northern red-legged frogs, Northwestern salamanders, long-toed salamanders, and rough-skinned newts were all historically common in various wetlands across the county. In more recent wetland studies between 1988 and 1995, the most commonly observed native species were Pacific treefrogs, Northern red-legged frogs, Northwestern salamanders, and long-toed salamanders; least common were rough skinned newts and western toads. One recorded species, the Oregon spotted frog, was not observed during that study and could be extinct in the county. One invasive species, the American bullfrog, has continued

extending its range since 1995 and is causing concern as a predator, competitor, and carrier of the highly lethal Chytridiomycosis pathogen as it disperses throughout the county.

The most significant finding from our wetland surveys was that no single wetland or group of similar wetlands encompassed the diversity found among all wetlands. In fact, no single wetland exhibited more than approximately 65 percent of the total vegetation, amphibian, bird and small mammal biodiversity found among all wetlands. This finding indicates that each wetland is unique and is instrumental to maintaining the entire regional biodiversity. In general, the regional richness of wetland species in the county remains relatively high although a few species have been noted only sparingly in recent years. Interestingly, the greatest biodiversity for vegetation, amphibians, birds and small mammals has been identified at wetlands owing their more stable hydrology to active beavers and their dams. Invasive species tend to be more common in hydrologically disturbed wetlands in the urban areas of King County and (native) species richness, for mammals and amphibians, in particular, tends to be lower in these same areas. Overall bird richness may have actually increased in some areas (attributable to the increase of generalist and exotic species) but the loss of more sensitive species has probably occurred as the landscape has been fragmented and disturbed.

Moss Lake is part of a bog wetland complex in King County's Moss Lake Natural Area. Photo: Jennifer Vanderhoof.

Mallard ducks are a common waterfowl in the region. Photo: Laurel Preston.

Cross-wetland diversity and within-wetland diversity seems to have declined over the last 150 years in the lowlands of the county as various stages of land development transformed the forests. Land clearing began in the mid-1800s and was followed quickly by agriculture; urbanization in the outlying areas of the county during the last few decades has quickly altered the landscape surrounding wetlands and changed vegetation and hydrologic patterns that support wetland habitat diversity and species richness. This pattern has not occurred in either the foothills or the alpine areas of the county. Therefore these wetlands are less disturbed.

Lake Biodiversity in King County

The natural biodiversity of the lakes of King County is strongly influenced by geography. The county runs from the Cascade mountain crest to the shores of Puget Sound, covering all three different Level III ecoregions (Puget Sound Lowlands, North Cascade, and Cascade). The geology, elevation, climate, and ecology in these three ecoregions are all different, and these differences in environmental factors determine the natural biodiversity of the lakes and also influence the risks, vulnerability, and impacts to that biodiversity.

All of King County below 305 meters (1,000 feet) elevation is in the Puget Sound Lowlands ecoregion and has just over 1,000 lakes and ponds. Similar to the high mountain lakes, the lowland lakes were formed during the last glaciation. Most of the smaller lakes are recessional outwash lakes, and the two largest lakes, Sammamish and Washington, are semi-fjord like lakes gouged out by the glacial advance. Most of these lowland lakes are shallow and small with only 50 of them greater than 1 hectare (2.5 acres) in size and only 7 greater than 100 hectares (247 acres). The Puget Sound ecoregion also has the highest density of human population and development pressure in the State.

Lake Washington is the largest lake in King County and the second largest lake in Washington, and it provides one of the most dramatic examples of human impacts on the biodiversity of lakes. In 1916 a Ship Canal was opened between the Lake Washington (via its connection to Lake Union) and Puget Sound, and the plumbing of the lakes drainage system changed from discharging through the Black River at the southern end of the lake to discharging ten miles north though the Ship Canal and locks. These modifications decreased lake elevations by nine feet, changed flow patterns and the time water stays in the lake, and promoted shoreline development and industrial activity, particularly around Lake Union. The sediments in Lake Union have been degraded by these activities such that there is little benthic fauna left in the lake.

The historic degradation of water quality in Lake Washington from increased population, development, and effluent discharge into the lake and the lake's subsequent recovery after the removal of sewage effluent is one of the best known examples of pollution and recovery of a large lake anywhere in the world. These and other modifications have had significant impacts on the biodiversity of Lake Washington. Some of the most dramatic and therefore best known impacts are the alteration of the phytoplankton population from an oligotrophic high-clarity low-productivity community, to a eutrophic high-productivity cyanobacteria-dominated 'Lake Stinko' of local media fame, and back to the mesotrophic lake phytoplankton community enjoyed today. This phytoplankton shift resulting from human-caused changes in nutrient loading in the lake resulted in documented modifications to the zooplankton and fish communities.

Current research is focusing on how picoplankton and nanoplankton (the really little algae) determine how the lake's ecosystem functions. Very little data exists on the current populations of these small plankton, but changes in the water quality over the past 100 years have probably had impacts on the biodiversity of these communities as well. How these changes translated into impacts on higher trophic levels and the overall biodiversity of the lake is impossible to determine with the data we now have, but it is a good assumption that impacts occurred.

Canada geese are very common to Lake Washington. Photo: Jennifer Vanderhoof.

On the other end of the size scale from nanoplankton, there have been numerous manipulations of the vertebrate, invertebrate, and plant assemblages in the Puget Sound lowland lakes, even greater than introduction-caused impacts in the alpine lakes. The current fish assemblage in Lake Washington has multiple established populations of non-native fish species that were officially and unofficially introduced to the lakes by state agencies, anglers, and private citizens. To name only a few, carp, perch, large and small mouth bass, weather loach, corbicula clams, red swamp crayfish, goldfish, neomycid shrimp, American bullfrogs, mute swans, nutria, Eurasian milfoil, elodea, and hydrilla are all non-native species with currently established populations in King County lakes. Every exotic species that is introduced into the native ecosystem has impacts and repercussions up and down the trophic ladder. Introduced non-native species represent the greatest current threat to the biodiversity of King County lakes. It is assumed that new introductions will continue to occur and how they will impact our lakes is unknown. These impacts to the biodiversity of the lowland lakes is probably mediated by the size and productivity of the lakes, similar to what is observed in the alpine lakes, but here too additional studies needs to be conducted to gain a better understanding.

In the North Cascade and Cascade ecoregions, which together comprise the mountainous eastern half of King County, a majority of high alpine lakes appeared with the recession of the last glaciation around 13,000

to 17,000 years ago. In the North Cascade portion of King County, north of Snoqualmie Pass, lies an area of lakes formed from glacial scouring. These lakes sit in rock basins, mostly between 1,000 metes (3,300 feet) and 1,830 metes (6,000 feet) in elevation. Some reside in steep-sided cirques where snow and ice accumulate to great depths and the lakes may remain frozen well into summer. These lakes tend to have the deep azure color characteristic of high alpine lakes. Other lakes occupy broader basins surrounded by alpine forest and meadows. Two-thirds of the Alpines Lakes Wilderness is in King County, and 490 lakes are in the county's portion alone. Of those, 193 are 4 hectares (10 acres) in size or larger. These areas were explored well before the turn of the 20th century as miners and railroad surveyors penetrated the wilderness in search of ore and routes. Their trails have been adapted by hikers to gain access to the alpine areas after they were abandoned by miners.

As a result of the mountainous topography, elevation, and isolation, many of these lakes were not naturally colonized by fish after the glacial retreat. Instead, many species of amphibians and frogs found relative safety in these fishless lakes for breeding. By the early 20th Century, however, federal, state, and county agencies were stocking many of these wilderness lakes, including the small high-elevation lakes, primarily with non-native brook trout, rainbow trout, and cutthroat trout. Although the fish stocking of many of these lakes provided excellent recreational opportunities, the introduction of a top predator into an ecosystem where it did not co-evolve had significant impacts on the biodiversity of these alpine lakes. Many of these lakes have seen alterations in the populations of macroinvertebrates and of native amphibians, such as the long-toed salamanders. Alterations at these trophic levels are assumed to create a cascading effect though the ecosystem of the lakes.

How strong the impact of non-native fish introductions is on the native biodiversity appears to be dependant on the size and productivity of the lake, with the impacts apparently dampened in larger more productive lakes. What the thresholds for these effects are has not been clearly defined, nor is it known how quickly the biodiversity of these lakes can recover, or if recovery will occur after the removal on non-native fisheries. Currently, the impact of fish introductions into high lakes that did not have native fish populations is being studied, and stocking has been suspended in many of these lakes in the North Cascades National Park (outside of King County to the north). The suspension of fish stocking in lakes that did not have native populations is also being considered for the Alpine Lake Wilderness area in King County.

Another threat to diversity is the impact to our lakes from global climate change. We are already seeing some signals of local climate change in our lakes in modification of the timing and duration of thermal stratification and in the reproductive cycles of zooplankton. What long term impacts these thermal modifications will have is not definitively known, but there is no debate that if temperature increase, the probability of maintaining, let alone recovering, our native salmonid runs will be in serious jeopardy. If our streams and the surface waters continue to warm, the cold bottom waters of lakes Sammamish and Washington may provide a thermal refugia for cold water species, but only if we can protect water quality sufficiently to maintain adequate concentrations of dissolved oxygen. Low summer dissolved oxygen in Lake Sammamish and some of the smaller lakes that thermally stratify decreases the portion of these lakes capable of serving as thermal refugia. The low dissolved oxygen in the bottom of the lake is a result of the increased productivity in the lake as a response to non-point loading of nutrients and increased primary productivity. These problems makes the protection and the improvement of the water quality in these lakes as important as ever.

Protection of the biodiversity of the lakes in King County depends on protecting the biodiversity of our local rivers, streams, and wetlands. This local effort will not be successful if it is not coupled with a broad-scale approach to correcting activities that decrease the biodiversity of these waterbodies. Reducing pollution and protecting water quality is a local and regional issue, and to succeed needs to be coupled with a global effort to control the spread of exotic species and address the impacts of global climate change.

White-tailed ptarmigan are an alpine species. Because they live and breed at such high elevations, they have few predators and are therefore not very skittish around people. Photo: Jennifer Vanderhoof.

Rivers and Streams of King County

The diversity of streams in the county is a reflection of the diversity of its geography. From the small rivulets that begin high in the Cascade Mountains, to the brooks that flow gently across the lowlands, to the five major rivers of the county, there are over 4,800 kilometers (3,000 miles) of perennial streamcourses in King County.

Despite the impressive total length, King County has no rivers that are longer than 150 kilometers (93 miles). For two of the rivers—the South Fork of the Skykomish and the White—only a portion of their length flows through King County. But geography has as much to say about river length as jurisdiction. The distance from the Cascade Crest to the shores of Puget Sound is short and the valleys that carry the major rivers are glacially carved, narrow, and relatively straight. From north to south, the major rivers of the county (total length of the river is in parentheses) are: The South Fork of the Skykomish (51 kilometers; 32 miles), the Snoqualmie (130 kilometers; 81 miles), the Cedar (90 kilometers; 56 miles), the Green-Duwamish (at 150 kilometers, 93 miles, the longest), and the White (122 kilometers; 76 miles). (See Landscape Diversity map for major rivers in King County.) Each of these has its headwaters in the Cascade Mountains, where they tumble down the steep terrain from snowfields and glaciers through narrow, steep-walled canyons into low elevation glacier-carved valleys, and finally flow alone or as tributary into larger rivers, then into Puget Sound. Along this path from mountains to Sound, each watercourse picks up numerous tributaries that drain the foothills and lowlands. A few small streams drain coastal lowland areas and empty directly into Puget Sound.

South Fork Skykomish River

The South Fork Skykomish River begins in the steep, heavily forested, deep-snow country of the Cascades near Thunder and Spark Plug Mountains in NE King County. The river flows generally west and northwest for about 32 miles (51 kilometers) to its confluence with the North Fork Skykomish River, in Snohomish County (the county directly north of King). The river is a part of the larger Snohomish River system that empties into Puget Sound at Everett, Washington.

All along its 32-mile (51-kilometer) course, the South Fork river picks up numerous moderate-sized tributaries, which are all important to the anadromous and resident salmon populations of this drainage. These include the Foss and Miller Rivers from the Alpine Lakes Wilderness from the south, the Beckler from the north, and Index and Money Creeks farther downstream. The South Fork and its major tributaries possess mountain-stream characteristics: moderately steep gradients, extensive rock and cascade channel forms, with deep pools and clear, cold waters. Where the gradients are not as steep, the mainstem South Fork and its tributaries are the major spawning and rearing areas for Chinook salmon in the greater Snohomish watershed and are home to bull trout and Dolly Varden, chars of the genus *Salvelinus*.

In its lower reaches, the South Fork flows through a deep, gravel-bedded valley typical of river valleys below the west slope of the Cascades. Here the river's slope moderates and the stream takes on a more sinuous character. Gone are the bedrock cascades and chutes, and in their place are rapids and riffles of boulder and cobble. Steelhead and cutthroat trout make use of small pools of quiet water immediately downstream of these large blocks of stone. Occasional large jams of logs create low dams that slow the river's flow and allow gravel to accumulate on the rough bed. These areas are the spawning sites for anadromous fishes. The jams also create most of the deep pool habitat found in the river by forcing the river to cut deeply into the bed and banks; these pools are refuge and rearing habitat for the offspring of the salmon.

The South Fork Skykomish River flows north and out of King County near the community of Baring at the foot of the Cascades. Here it joins the North Fork Skykom-

ish to become the mainstem Skykomish River. From the forks, the Skykomish River flows another 48 kilometers (30 miles) to join the Snoqualmie River to become the Snohomish River near the town of Monroe in Snohomish County.

Snoqualmie River

The Snoqualmie River in spring.

A companion river to the Skykomish system, the Snoqualmie River has its headwaters in the high and snowy Cascades as well. The Snoqualmie has its headwaters near Le Bohn Gap below the glaciers of Mt. Hinman. From there the river flows approximately 81 miles (130 kilometers), first as the Middle Fork, then as the mainstem Snoqualmie. The mainstem Snoqualmie then meets the Skykomish River to form the Snohomish River. Along the upper part of its route, the river picks up tributaries—the Taylor and the Pratt and two other forks, the North Fork Snoqualmie and the South Fork Snoqualmie—before dropping 82 meters (268 feet) over Snoqualmie Falls to the valley below. These upper rivers are steep and swift, and car-size boulders and bedrock ledges are common. In the occasional broad parts of the narrow upper valley, the river braids and slows, gravel beds form and pools deepen; these stretches are home only to resident cutthroat and introduced rainbow and brook trout. Snoqualmie Falls is a complete barrier to anadromous salmon upstream migration. Regular suggestions are made to provide some sort of passage or transport for anadromous fish above the falls but no action has been taken. If this were to occur, the implications for native biodiversity in the upper watershed are likely to be significant.

Below the falls, the character of the river changes dramatically from mountainous to lowland, and the river meanders slowly northwest across a broad, flat valley floor another 58 kilometers (36 miles) to its confluence with the Skykomish River. Across the valley floor, the river has extensive gravel bars and glides but very few deep pools. Along its valley length lie farms and fields, and much of this portion of the river is revetted (35 percent of the left bank and 30 percent of the right bank). Small amounts of large wood, so important to the formation of salmon habitat, can be found here, but not a single large jam occurs on the river. Like many other lowland rivers in King County, the jams were removed earlier in the century, sometimes for navigation, occasionally for firewood, most recently for flood control. Nevertheless, the mainstem is important habitat for populations of Chinook salmon, pink salmon, chum salmon, and steelhead.

Along its lowland course, the river picks up several tributaries from the foothills along the river: Griffin Creek, the Tolt River, Harris Creek, and Cherry Creek from the north; the Raging River and Patterson Creek from the south. The major river tributaries tend to be relatively steep, but they still provide extensive habitat for Chinook, chum, and coho salmon. The lowland tributaries have lower gradients, and often their headwaters are in large beaver ponds and wetlands in the uplands. The combination of gentle gradient and ponds provides excellent conditions for coho salmon. In fact, these lowland tributaries of the Snoqualmie produce more coho salmon in a single year than any other comparable system in the state of Washington.

Chinook salmon are listed as "threatened" under the federal Endangered Species Act. The largest species of salmon found in the Northwest, they are also commonly known as king salmon. Photo: Laurie Devereaux.

Cedar River

The shortest river wholly contained within the county is the Cedar River. The Cedar begins as the North Fork Cedar at Lost Lake on the slopes of Meadow Mountain in east-central King County and flows approximately 90 kilometers (56 miles) to Lake Washington in the lowlands. Along its route, it passes through the moderately steep mountain terrain of the upper Cedar River watershed for about 23 kilometers (14 miles) until it reaches Chester Morse Lake, the storage reservoir for the water supply for the City of Seattle. Above Chester Morse Lake, the river has three main tributaries: the Rex River and the North and South Forks of the Cedar. The 9.7 to 11.3 river kilometers (6 to 7 river miles) above the lake present excellent pool and riffle profiles as the slope of the channel moderates and the valley widens a bit. The streamside vegetation through this reach has improved greatly since the logging days of the early 20th Century. The City of Seattle is managing the watershed (and has been for the last 20+ years) for mature forest conditions and has developed a habitat conservation plan for the watershed that addresses terrestrial and aquatic ecosystems and their inhabitants.

From the dam at the outlet of the reservoir, the river travels through a canyon-like reach for two miles. The channel gradient is steep here, with numerous falls and cascades and a boulder-dominated stream bottom. The valley walls recline a bit for the next 10 kilometers (4 miles), but the valley remains narrow and steep-walled. The channel moderates and the streambed is rubble and large cobble with occasional rapids and deep pools. For the next 13 kilometers (8 miles)—until the Landsburg Diversion Dam—the valley alternately narrows and widens, the gradient moderates, and the streambed is mainly large gravels and rubble with many long, deep pools and broad gravel riffles. The streamside has reforested well from old timber operations, and the forest is mixed conifer and deciduous. At the Landsburg Dam, water is diverted into a pipeline for transport to Seattle, approximately 35 kilometers (22 miles) downstream.

From the diversion dam, the Cedar winds west and northwest through a shallow, narrow valley, through increasingly intense residential development, for about 19 kilometers (12 miles) until the valley widens dramatically. The gradient is moderate through most of this reach—except for the steeper upper 1.6 - 3.2 kilometers (1 - 2 miles)—and occasional steep gravel walls occur throughout. These walls, some 150 feet high, are the primary sources of the spawning gravels for this section of the river, and the most intense spawning activity of the river is observed through this long reach. Chinook, coho, and abundant sockeye salmon spawn in the mainstem throughout. Taylor Creek and Rock Creek are small but important spawning streams in this reach.

Below this section, the Cedar River winds westerly for 11 kilometers (7 miles) to its confluence with the southern end of Lake Washington. The valley is quite broad and flat, and intense residential development occupies the valley floor and the plateaus above the valley. Commercial uses cover the valley floor over the last mile or so to the lake. Much of the riverbank in the last 4 miles has revetments to prevent the river from meandering and threatening homes and businesses; the entire south bank is a railroad embankment. A recent landslide in the lower half of this reach has formed some of the best salmon habitat in the lower river, and fishery agencies and County biologists are working together to protect the slide in its present condition. The river receives heavy recreational use throughout this reach and the reach above, and the logs and debris naturally delivered into the river may present barriers and sometimes be hazardous to boaters. Where the river exits its valley, the Cedar is channelized for the last 3 kilometers (2 miles) or so to Lake Washington. This channel was constructed at the time the Cedar was diverted from its original confluence with the Green River; this diversion

Sockeye salmon are the most common salmon species found in the Cedar River. Photo: Ray Heller.

occurred in 1916 to supply water for lock operation in the Lake Washington Ship Canal (for more information, see below).

The Cedar River is home to several species of salmonids and, for its size, supports abundances that are among the greatest in the state. Sockeye salmon, once rare to potentially non-existent in the system, have reached upwards of 600,000 adults in recent strong years; coho salmon use almost all accessible tributaries in the Cedar, and chinook salmon spawn beneath the gravel walls of the middle reaches (chinook have not been as abundant in recent years, however, and many scientists are concerned for their survival). One species—the pygmy whitefish—is found in King County only in Chester Morse Lake and the Cedar River above the lake. An isolated population of bull trout also make use of the Cedar River and Rex River above Chester Morse Lake (see fish discussion in Section 1.3).

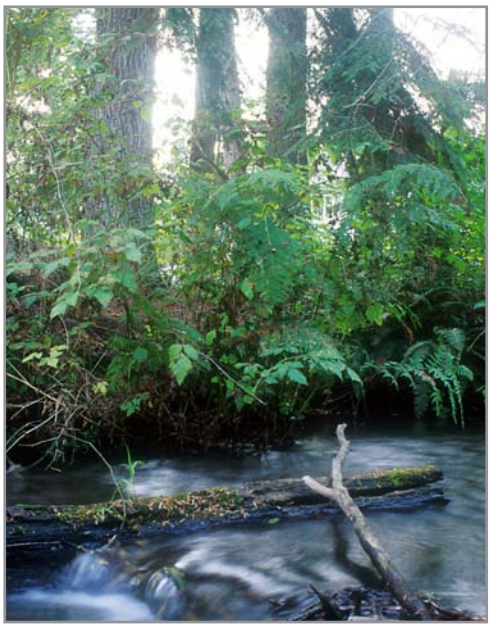
Lowland Streams of the Lake Washington Watershed

In addition to the Cedar River, which flows into the southern end of Lake Washington, the larger Lake Washington Watershed also contains a number of lowland streams that enter its northeastern tributary, the Sammamish River, and its companion lake, Lake Sammamish, which lies immediately over a ridge to the east of Lake Washington (see Landscape Diversity map). These streams include: Issaquah Creek, which drains the foothills of Tiger and Taylor Mountains and enters Lake Sammamish at its southern end; Big Bear Creek, which drains the flatlands to the north of Lake Sammamish and enters the Sammamish River just downstream of the lake; and Little Bear, North, and Swamp creeks, all lowland streams that enter the Sammamish River and typify the lowland streams of the county and, indeed, all of the Puget Lowland (see Riparian discussion in Section 1.3).

Issaquah Creek is somewhat of an exception to the lowland stream type in King County because its headwater tributaries, Holder Creek and Carey Creek, rise on the western and northern slopes of Tiger Mountain at about 460 meters (1,500 feet) elevation and flow swiftly down to the main valley floor. On the valley floor, Issaquah Creek possesses a shallow gradient and has the quintessential pool/riffle character of highly productive coho salmon streams. During the mid 20th Century, this valley was lined with small farms and fields. However, the decline of agriculture in this valley has allowed the regrowth of a dense riparian zone of alder and young conifer. The upslope streams, Fifteenmile and Holder creeks, are small and steep with occasional cascades and falls that limits the upward migration of anadromous salmon, but resident cutthroat trout are found above many of the barriers. Genetic analysis suggests that these populations may have been isolated from their lowland kin for 7,000 to 9,000 years, probably as a result of the decline of the glacial meltwater flow from alpine glaciers far to the east. Issaquah Creek's lowland valley, which is very broad and flat for the size of the present stream, is a remnant of that glacial flow. The fishes found above the present-day falls may have found their way into these streams at that time. In addition to these native trout, Issaquah Creek has populations of chinook, coho, steelhead, and sea-run cutthroat trout in its mainstem, and sockeye salmon in its East Fork.

The lowermost reach passes through the City of Issaquah, where a State of Washington salmon hatchery is located. During the upstream migration of salmon in the fall and winter, the hatchery uses a shallow weir to divert chinook and coho salmon adults from the stream into holding ponds for use in an artificial propagation program. The adult salmon are sorted, eggs are taken from the females and milt taken from the males. Any salmon that are in excess of the number required to satisfy the production goal are then released into the creek above the weir. Sockeye salmon, a species that are not propagated in this hatchery, tend to migrate upriver about the same time as chinook; these fish are passed through the weir without diversion.

Big Bear Creek is typical of the low-gradient, meandering character of King County's lowland creeks. Like the others, Big Bear Creek rises from a small headwater lake and wetland that are set amid second- or third-growth forest in a watershed that is becoming increasingly urban. Big Bear Creek flows through many wetlands—old beaver ponds in its upper half—for about 19 kilometers (12 miles) to its confluence with the Sammamish River. Along its path, Big Bear Creek flows from headwater forests and wetlands, alongside a golf course, through an occasional subdivision, past old



Cottage Lake Creek , a tributary to Bear Creek, is home to several salmon species as well as freshwater mussels. Photo: Ray Heller.

farms and horse pastures, and, finally, through urban development before it enters the Sammamish river. Despite the urbanization and other development, the creek retains considerable habitat for salmon: Chinook, sockeye, coho, and cutthroat trout are found throughout the stream, even into its uppermost reaches. Until recently, Big Bear Creek was the most productive stream for coho salmon in all of Puget Sound. Portions of the stream have some rather unusual inhabitants, including freshwater sponges and the largest populations of the western pearlshell mussel (*Margaritifera falcata*) remaining in King County.

Several streams occupy the lowlands to the west—Little Bear, Swamp, and North Creeks—and are quite similar in slope, morphology, and size to Big Bear, but their watersheds have experienced far more development than that of Big Bear. Nevertheless, coho salmon and cutthroat trout continue to find suitable habitats in these streams, and their presence is indicative of the resilience and tenacity of the family of salmonids.

Green-Duwamish River

The Green-Duwamish River originates in the high Cascades in the vicinity of Blowout Mountain and Snowshoe Butte, about 48 kilometers (30 miles) northeast of Mt. Rainier. From its headwaters, it flows approximately 150 kilometers (93 miles) to Puget Sound; it is the longest river in King County. For its uppermost 40 kilometers (25 miles), the river flows through narrow steep-walled valleys and heavily forested terrain of the upper Green River watershed. The stream flow over waterfalls and steep cascades for its first 16 kilometers (10 miles) until it meets Sunday Creek, the main tributary in this landscape. From here for the next 24 kilometers (15 miles), the valley widens and flattens, and dense stands of bottomland conifers and deciduous trees line the river. The valley walls are still steep and densely forested; the area is used primarily as a watershed for the City of Tacoma's water supply. Some clearcuts are evident on the valley slopes, but that activity has slowed in the last decade.

Flowing through this rugged landscape, the Green River receives several tributaries: Friday Creek, Sawmill Creek, Champion Creek, Smay Creek, and Charlie Creek.

At about river kilometer 109 (river mile 68), 40 kilometers (25 miles) from the headwaters, the river enters Howard Hanson Reservoir, a flood control reservoir created by the US Army Corps of Engineers' Howard A. Hanson Dam in Eagle Gorge at river kilometer 103.8 (river mile 64.5). The North Fork of the Green River is the major tributary to the reservoir. Three miles below the storage dam, the City of Tacoma maintains a water supply diversion structure (Tacoma Headworks). This facility represents the present upper limit of access for anadromous fish in the Green River.

Below Howard A. Hanson Dam and the Tacoma Headworks, the river enters the Green River Gorge, a steep-walled, forested canyon known for its whitewater. The river is moderately steep throughout the gorge, with plunges and drops among boulders and rock shelves. Much of the land in this area is owned by Washington State Parks, and King County has property holdings in the gorge as well. After 26 kilometers (16 miles), the Green River emerges into the broad river valley of the lowlands. From here the river meanders over a broad valley floor through an agricultural area with a few stands of deciduous and conifer trees lining the banks. Major lowland tributaries enter the Green River in this reach: Newaukum Creek, Crisp Creek, Burns Creek, and Soos Creek. Portions of the river are revetted here, but the County owns considerable land where the river

is free to meander naturally across the valley floor: Metzler and O'Grady Parks contain some of the finest river habitat features remaining in the Green River watershed.

Downstream at about river kilometer 42 (river mile 26), the Green River enters the lowland urban area of King County. From here to the river's mouth in Elliott Bay, the river has been extensively channelized and diked. In its lower 16 kilometers (10 miles), the Green River is called the Duwamish River and is surrounded by the industrial heart of King County. In this area, the river once received three major tributaries: the White River, the Cedar River, and the Black River. Each of these tributaries has been rechanneled out of the Green River system, and these diversions have reduced the normal river flow by a third. First, the White River was channeled out of the Green in 1915, after a large flood in 1906 deposited a log jam that forced the White south into the Stuck River, a tributary to the Puyallup River. After long and arduous negotiations, its flow was transferred permanently into the Stuck River and the Puyallup River to the south. The Cedar River was diverted out of the Green-Duwamish River and into Lake Washington in 1916 to provide water to operate locks on the newly constructed Lake Washington Ship Canal. The opening of this same canal lowered Lake Washington by 2.4 meters (8 feet) and dried up the Black River, which was once the lake's outlet to the Green-Duwamish River.

No other river in King County has undergone the level of transformation that has characterized the Green River, and despite all these changes, salmon continue to return to spawn every year. After the closing of Howard A. Hanson Dam in 1963, salmon could no longer migrate into the upper watershed through Eagle Gorge. This area was once the major spawning ground for steelhead, and possibly for a spring run of Chinook salmon (there is some disagreement among experts on this question). At the present time, migrating salmon are stopped at the Tacoma Headworks. Juvenile Chinook from a hatchery program are trucked above the dam, however, to make use of the rearing capacity of the upper watershed (and this program explains the distribution of Chinook on the Rare, Threatened, and Endangered Species map). In a few years, as part of an enhanced water storage project undertaken by the Corps of Engineers and the City of Tacoma, a fish lift will be installed to pass adult salmon above the dam. In the meantime, Chinook continue to use the river below the dam for spawning and rearing, especially the reach below the Green River Gorge downstream to the urban area. Chum salmon use this reach as well but mainly occupy the side channels of the middle Green. In recent odd-numbered years, a large population of pink salmon has established itself in the Green River to the surprise of many fishery biologists. This population was expected to reach nearly one million in early 2007.

The lowland tributaries of the Green River tend to be very low-gradient systems that flow along the valley floor (Burns and Crisp creeks, for example) or originate in the upland plateau to the south (Newaukum Creek). All the lowland tributaries have been affected by the agriculture use that has dominated the valley for over 100 years. Portions of these streams have been channelized, dredged, and re-directed along property lines and roadsides. Little of the native riparian habitat remains, even in the lower, wooded valley of Newaukum Creek. This reach remains forested but is dominated by deciduous trees that have colonized the cutover areas. Nevertheless, these streams are used by coho salmon and some steelhead, and many restoration actions are underway to regain lost habitat. In the lowermost reaches of the river, few streams remain above ground through the industrialized landscape. An exception is Hamm Creek, whose restoration became the personal crusade of one local resident for 20 years and has resulted in a much-restored stream amid the otherwise-industrialized landscape.

Howard Hanson Dam and reservoir on the Green River.

The mouth of the Green-Duwamish River empties into Elliott Bay via the heavy industrial area of Seattle that was once the estuary of the river. Little of the estuary remains—about 11 hectares (28 acres) in a single small area near Kellogg Island in the lowermost river. Recently, the US Army Corps of Engineers and King County have been cooperating in projects to regain some of the lost estuarine habitat.

White River

The White River is 122 kilometers (76 miles) long and has its headwaters on the northeastern slopes of Mt. Rainier from meltwater of the Emmons and Fryingpan glaciers. The river gets its name form the color of the glacial flour that is carried by the flow from its headwaters. The river flows through Pierce County for about 40 kilometers (25 miles) until the confluence with the Greenwater River. From this confluence downstream for approximately 51 kilometers (32 miles), the White River forms the southern boundary of King County. The uppermost reaches of the White River (in Pierce County) flow generally north through mountainous terrain, between steep, forested valley walls that rise quickly from the river's edge to over 1,830 meters (6,000 feet). The upper gradient of the White River is precipitous, with many falls, cascades, and steep rapids, and a streambed composed of large boulder and bedrock. The major tributaries in this section are Huckleberry Creek, Silver Creek, and Fryingpan Creek.

Lake Tapps is an artificially enlarged lake used as a reservoir for power generation in the White River watershed.

The gradient and terrain moderate somewhat near the community of Greenwater, where the White picks up the Greenwater River as a major tributary. From here, the river flows for about 35 kilometers (22 miles) west through an intermittently broad and narrow valley with steep, densely forested sideslopes. The stream bed maintains its mountain-like character throughout most of its length but some pool and riffle sections can be found where the valley broadens and the stream's gradient lowers. Just upstream of the town of Buckley, near river kilometer 48 (river mile 30) and 74 kilometers (46 miles) from its headwaters, stands Mud Mountain Dam, a flood control dam completed in 1947 to control severe flooding in the lower Puyallup River valley. The river below the dam is a fast-flowing glacial stream with a boulder and rubble bed, and few areas are level enough to allow gravel accumulation.

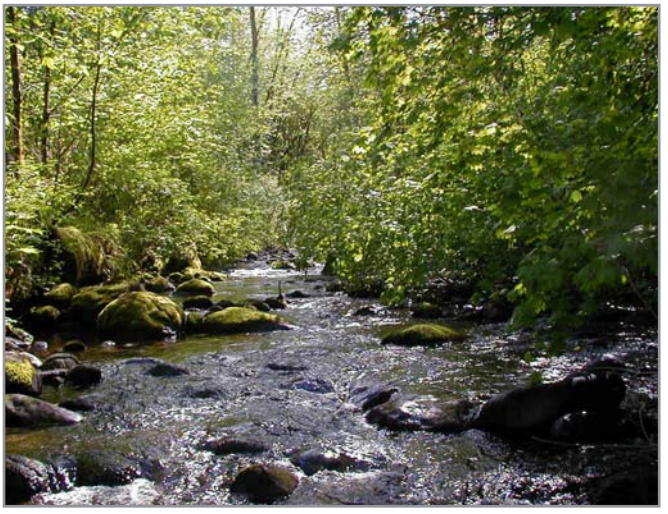
Five miles below the dam is a second structure, a diversion dam that for the past 100 years or so has shunted water off the river (to Lake Tapps, an artificially enlarged lake that is used as a reservoir) for power generation. For most of that time, the diversion reduced the flow dramatically in the 34 kilometers (21 miles) of the bypass reach. The diversion is no longer used to produce power; instead, some water is still diverted to maintain the artificial lake that is surrounded by residences and is used mainly for recreation. During the decades that flow was diverted for power production, the bypassed reach of the river often experienced flows that were a small percentage of the natural flow. In fact, a flow record from 1959 shows that the flow in one area of the bypass reach of the river reached almost zero during one diversion episode.

From the diversion dam downstream for about 19 kilometers (12 miles), the White River flows through a relatively confined valley averaging 1.6 kilometer (1 mile) in width with steep valley walls that rise abruptly to about 122 meters (400 feet). It remains turbid with glacial silts and is characterized by continuous braiding and channel splitting, an outcome of regular sediment flushes from Mud Mountain Dam and the variable flow regime imposed on the river. Negotiations are underway to address flow management issues in the hope of regaining some of the ecological function lost as a result of past river management.

At river kilometer 12.9 (river mile 8), the White River takes an abrupt turn to the south to follow the old Stuck River channel to its confluence with the Puyallup River. In 1914, a flood control project jointly carried out by King County and Pierce County diked off the White River channel and permanently redirected the flow of the White into the Stuck River and on into the Puyallup. In this lowermost reach, the White is completely diked and channelized to protect the adjacent farmland and industry from flood damage.

Despite the modifications, several species of salmon use the White River for spawning and rearing. A run of Spring Chinook , the only spring-type population this far south in Puget Sound, still uses the upper White and its tributaries—Huckleberry Creek, the West Fork White, the Clearwater River, and the Greenwater River—for spawning and rearing. These fish are trapped at a facility near the diversion dam and hauled above Mud Mountain Dam, where they are released to continue their migration. A separate population of fall Chinook uses much of the lower White River, despite the glacial flour that colors the water. Likewise, coho salmon use much of the lower White and its upper tributaries for spawning, but the numbers in the upper watershed are fairly low given the steep and swift character of the upper tributaries. Pink salmon (whose numbers have increased recently), chum salmon, and steelhead also use the lower White River for spawning.

Riparian Habitats of the Lowlands, Foothills, and Highlands



Many of King County's creeks have been channelized or otherwise constrained. Here a section of Griffin Creek flows in a relatively natural state.

Riparian habitats are often characterized by particular trees and shrubs species that line the banks of most rivers and streams in the lowlands and foothills of King County. These habitats tend to be used by a diversity of species out of proportion to the area represented by streamsides. Although riparian habitats occupy only about 2 percent of the landscape, they contain more species than the surrounding uplands. Over 50 percent of the wildlife species of Western Washington (birds, mammals, and herptiles) use riparian zones regularly. Some species like the Pacific giant salamander might be considered wholly dependent on riparian habitats because they breed in streamside forests and feed in the rivers and lakes bounded and protected by riparian habitats. In addition, riparian habitats provide critical functions to the aquatic habitats they bound: litter and insects for food, shade to moderate temperatures, large wood for instream habitat structure, and nutrient transformation that influences water quality. In most cases, small streams historically were bounded directly by the forest stands through which they flowed; any true riparian habitats tended to lie along the very stream edge and be very narrow. Typical plants of this zone along small streams include salmonberry, Pacific ninebark, several willow species, and red alder. Alongside larger streams and rivers in King County, the riparian habitats were historically among the most complex habitats in the landscape. The dynamics of flow in Puget Sound

rivers—floods and droughts—controlled the location, species recruitment and survival, and community composition of the riparian habitats. In a transect from river to upland, one could historically traverse willow breaks, newly sprouted cottonwoods, mature cottonwood, Oregon ash, and Sitka spruce, each species closely associated with the flood regime of the river. Along the river, the communities became more complex as various patches responded to the dynamics of the river and to the work of beaver in the sloughs and side channels. Given this complex array of habitats, ages, and communities, it is no surprise that riparian habitats are often considered keystones of richness and diversity.

Few examples of pre-settlement riparian habitats remain in the lowlands and foothills of King County. Most of the riparian habitats that now line our river and streams have been greatly simplified. The American beaver, an aptly named "ecosystem engineer," is now relatively rare compared to pre-settlement times, and their handiwork can no longer be found as easily (they are making a comeback in some places, however, and ecologists celebrate each evidence of a new beaver dam in the side channels of our rivers; for further discussion, see Mammal section, page 64). Furthermore, the flow regimes of our large rivers have been largely regulated to reduce flooding and the damage to homes and businesses; the damage to the riparian ecosystem has increased, however, as the disturbances mainly responsible for the variety of plant communities have been eliminated. Our riparian habitats today are dominated by red alder, and occasional cottonwood stands, some older than the dams that now regulate the river. The fate of future stands often rests with volunteers and agencies that sponsor riparian planting events to reinvigorate the habitats that were once invigorated by floods.

Seagrass meadows form valuable habitat for fish and invertebrates in the nearshore. Photo: Randy Shuman.

Despite the changes these lowland and foothill landscapes have undergone, the diversity of habitats supports a tremendous diversity of wildlife species. The high species richness is a function of the broad distribution of habitat types and the diversity of habitat types across the large area. However, these habitats are also prone to invasion by exotic species, both plants and animals, and are also the source of many non-native species that have invaded nearby native habitats. Often the species that occupy these habitats are either habitat generalists or species that are using the disturbed habitats for feeding while nesting in less disturbed habitats nearby. Others are seasonal migrants using the habitats as resting stopovers or winter feeding areas.

In the highlands and sub-alpine areas, riparian habitats are generally much reduced as headwater streams are quite small and often flow steeply through narrow canyons and gorges. These streams are often bordered by vegetation characteristic of the adjacent terrestrial habitats. In some low gradient areas, more extensive riparian habitats develop where beaver have dammed streams forming ponds or where small lakes interrupt the stream. The resulting pond and wetland systems provide complex habitats that support many species of birds, mammals, and amphibians. Distinctive plant types and communities may form in these wet areas and include saxifrage (*Saxifraga sp.*), willow-herb (*Epilobium sp.*), monkey flowers (*Mimulus sp.*), rein orchid (*Habenaria sp.*), and bluebells (*Mertensia sp.*). Where peaty soils form, sedges of the genus *Carex*, low shrubs of Labrador tea (*Ledum*) and bog laurel (*Kalmia*), and a few distinctive herbs such as marsh marigold (*Caltha leptosepala*). arnica (*Arnica sp.*), and pedicularis (*Pedicularis sp.*) can be found.

Puget Sound Marine Habitat within King County

King County contains four major marine habitats: backshore, intertidal and shallow subtidal, deep subtidal, and riverine/sub-estuarine. Descriptions of each of these habitats and the types of flora and fauna associated with them are provided below.

Backshore Habitat

The backshore is defined as that area of shoreline lying between terrestrial vegetation and the average high-tide line, which is affected by waves only during severe storms. Backshore areas support a variety of vegetation, dunegrass, for example, that are tolerant of salt spray and wind. This vegetation helps stabilize the shoreline so it does not erode away. Drift logs and other natural debris are deposited on the backshore over a large portion of the King County shoreline. Over 100 species of marine and terrestrial insects alone are associated with the backshore, and many bird species, such as shorebirds and swallows, forage on these insects.

Intertidal-Shallow Subtidal Habitat

Intertidal and shallow subtidal habitat includes rocky and soft bottom substrates that extend from the average high-tide line down to a depth where benthic aquatic plants are no longer found (i.e., the photic zone). Over 150 species of benthic (attached to the bottom) marine plants have been documented in King County.

Rockweed is a common species found in the upper elevations of rocky shorelines, and sea lettuce and the brown alga *Laminaria* dominate mid- and lower-intertidal rocky areas. In several patchy areas, the shallow subtidal zone also contains kelp forests (*Nereocyctis* sp.), which provide important ecological functions, such as cover from predators and rearing habitat for species such as rockfish, crabs, and shrimp. Seagrass (specifically, *Zostera marina*), one of the most important marine plants in Puget Sound, is common but intermittent along most of the shoreline. It stabilizes sediments and provides nursery area for young crabs, shrimp, and fish. There are continuous seagrass meadows along portions of Vashon Island and sections of the northern Puget Sound shoreline of King County in the subtidal zone.

Over 500 invertebrate species have been documented in King County intertidal/shallow subtidal habitat. The distribution of invertebrates is mainly related to substrate type. Geoducks (pronounced *gooey-duk*), the largest intertidal clam in the world, are found along most shorelines, as are other important commercial and recreational invertebrates such as Dungeness crabs and butter clams.

Burrowing anemone are somewhat common in Elliott Bay and other nearshore waters of King County. Photo: Jennifer Vanderhoof.

More than 60 species of marine fish use intertidal and shallow subtidal habitat in King County. This habitat is particularly important for juvenile Chinook and chum salmon and for three species of forage fish (surf smelt, sand lance, and Pacific herring). Surf smelt and sand lance spawning habitat occurs throughout King County's intertidal and shallow subtidal habitat, but the only Pacific herring spawning site in King County is in Vashon Island's Quartermaster Harbor.

Shorebirds and waterfowl, such as sandpipers, horned grebes, and great blue herons use intertidal and shallow subtidal habitats throughout King County to feed on vegetation and invertebrates.

Deep Subtidal Habitat

Deep subtidal habitat extends from the photic zone down to the seabed; in Puget Sound this region extends downward to about 268 meters (879 feet) off of Point Jefferson. The majority of King County's portion of Puget Sound is the deep subtidal habitat. Plankton in this habitat provide the basis of the Puget Sound food web and generate nutrients and oxygen for other organisms. Plankton species are not well documented in Puget Sound.

Over 500 benthic and 50 pelagic invertebrates have been documented in King County's deep subtidal habitats. Puget Sound, including King County, is home to the giant Pacific octopus, the largest octopus in the world, and to the giant acorn barnacle, the largest barnacle in the world. Other distinctive invertebrates in this habitat include the Puget Sound king crab and the commercially important spot prawn.

Over 150 species of marine fish use deep subtidals areas, including rockfish, adult forage fish, flatfish, and sharks. Several of the larger species, including the six-gill shark and wolf-eel, occur in King County waters. Commercially important marine fish include the salmon species, Pacific herring, and bottomfish, such as cod, pollock, and rockfish. Populations of Pacific hake, Pacific cod, walleye pollock, spiny dogfish, and several rockfish species have severely declined over the past twenty years because of over-harvesting, toxic contaminants, declines in prey resources, and changes in habitat quality.

Over 100 marine bird species are found in Puget Sound, and most of these species likely use King County marine waters at some point of the year. Some species are permanent residents, whereas others may be summer residents (breed), summer visitors (do not breed), winter visitors, or spring and fall migrants (for more information, see the discussion on birds in Section 1.3). Many of the seabird and seaduck populations are declining to dangerously low levels, and since 1970, the total number of marine birds in the region has dropped by 47 percent. Possible causes of these dramatic declines include reduction of prey (especially forage fish), oil spills, contaminants, and disturbance to breeding areas.

Nine species of marine mammals have been documented in King County waters. The Steller sea lion, harbor seal, and Dall's porpoise may be seen year-round, whereas the California sea lion, gray whale, and killer whale are seasonal visitors. Humpback whales and minke whales are uncommon visitors in King County waters. One record of a sea otter exists for King County waters. Killer whales were recently listed as endangered because of population declines. Causes of decline are thought to include effects from toxic contaminants, the once-common practice of capture for aquarium display, declines in prey abundance, and stress from whale-watching activities.

Riverine/Sub-estuarine Habitat

Riverine/sub-estuarine habitat includes the area where rivers or streams meet Puget Sound, which results in a mixture of salt and fresh water. Riverine and sub-estuarine habitats support a variety of species because of the complexity of habitat from the mixture of fresh and salt-water. This habitat provides feeding and refuge areas for a variety of animals including crabs, shrimp, salmon, seaducks, shorebirds, and sea lions. There are two large riverine/sub-estuarine areas within King County: the Duwamish River estuary, which empties into Elliott Bay along the Seattle waterfront, and the outlet for the Lake Washington Ship Canal, which empties into Shilsole Bay. Both of these systems are important for migrating salmon. There are several other smaller sub-estuaries within King County. The Duwamish River sub-estuary has been highly modified since the late 1800s, when the river was straightened and armored along most of the shoreline to facilitate navigation and industry. The Lake Washington Ship Canal was created in the early 1900s to provide a navigational link between Lake Washington and Puget Sound.

Historically there were large coastal wetland complexes (or salt marshes) throughout Puget Sound. The size distribution of these complexes has shifted downward over the past 150 years because of shoreline development. The median size is about three-fifths the historical size. The Central Puget Sound area, where King County is located, has had the highest loss of wetland complexes, with less than 30 percent of the historic wetlands still remaining today. The largest tidal marshes within King County, located within the Duwamish River and Elliot Bay, were almost entirely filled and developed over the past 100 years. Of the remaining wetland complexes in King County, over 60 percent occur on Vashon and Maury Islands. Furthermore, the remaining 40 percent on the mainland shoreline have been highly altered, whereas the wetland complexes on the islands have not been as severely altered because of less development pressures.

Submerged Aquatic Vegetation

There are only a few areas in Puget Sound with large tidal flats and huge expanses of seagrass beds, but because of the geology of the area these do not exist within King County. The Puget Sound shoreline in King County is dominated by relatively steep slopes, with a narrow shelf that was notched into by wave action as sea levels rose after the last glaciation. These shelves are relatively narrow, providing opportunities for patchy fringing seagrass beds (as opposed to large contiguous

beds). There is also a species of nonnative seagrass (*Zostera japonica*) present on the shelves, though it generally grows at a higher intertidal height than the native seagrass (*Z. marina*). Although there are fringing seagrass beds throughout King County, there are currently fewer areas with kelp beds (primarily *Laminaria* and *Nereocystis*); the majority occur along the shorelines of Vashon and Maury Islands. It is believed that the extent of kelp beds was much greater in the early 1900s. Sargassum, a nonnative algal species, is found throughout King County's marine shoreline in patchy beds. Although it does have the ability to displace native brown algae, it has also been shown that it generally supports a more species rich fauna community than the native brown algae.

Sediment Processes

Approximately 70 percent of the marine shoreline within King County has been armored or bulkheaded. These alterations have had a significant negative impact on the sediment delivery and transport processes. This armoring has caused the loss of 64 percent of all the eroding bluff sediment sources within King County. There has been a similar loss of accretion beaches, with almost 50 percent being lost, with a large portion of the remaining beaches being heavily altered by development. These impacts are more focused along the mainland shorelines, especially the northern half. The most intact shorelines are found along the southern most portions of the county and along Vashon and Maury Islands.

King County's Birds, Mammals, Herptiles, and Fishes

Animal species have been mentioned in each of the discussions above. Table 4 summarizes the numbers of vertebrate animal species in the county, as well as the vascular plant species. This section provides a more in-depth discussion of the birds, mammals, herptiles (amphibians and reptiles), and inland and marine fishes in King County.

Birds

The King County Breeding Bird Atlas, which was completed between 1987 and 2000, reports that 164 bird species are confirmed (135), probable (15), or possible (14)

Double-crested cormorants are frequently seen on pilings along King County shorelines.
Photo: Jennifer Vanderhoof.

breeders in the county. The distribution and abundance of these species has shifted over the past 150 years as a result of many factors, the most significant of which has been the impacts of logging and subsequent development. Table 4 indicates some of the changes that have occurred in bird populations in King County since the period of Euro-American settlement.

Some of the species in this table, as well as some others that are not listed on the table, have undergone population increases and decreases over the past 150 years as a result of the succession of logging and subsequent change of the cleared lands to agriculture, to rural and urban development, and even back to forest. The landscape continues to change, and as a result, bird populations will continue to change. Generally speaking, the bird species that have increased are those that can adapt to human presence and habitation (Mallard and American Crow, for example), and those that do best with edge habitat and fragmented landscapes. Red-tailed hawks are a perfect example of the latter: their numbers have increased regionally and nationally because of the mosaic of forest and open area they prefer. White-crowned Sparrows (and likely Bushtits as well) have increased in King County because of the increase of mosaic of shrubby habitat and open spaces.

The Common Nighthawk is another species whose population trends have changed dramatically over the past 150 years. Prior to Euro-American settlement, they were restricted to breeding on gravel bars exposed by rivers declining in level during the spring or perhaps in clearings caused by natural fires. They increased in numbers when forests were cleared and they took advantage of the open areas. But with development and reforestation, they have declined again. However, the rate of their population decline in King County seems inconsistent with the recent changes in the landscape,

Table 4. Number of Vertebrate Animals and Vascular Plants Known to Occur in King County.

Species Group	Number of Species	Qualifier
Birds[1]	221 (5 introduced)	breeding and non-breeding; common, uncommon, or usually seen on an annual basis
Mammals[2]	69 (8 introduced)	Breeding species. Gap Analysis makes the assumption that if all vegetation types are adequately represented in biodiversity management areas, then most plant and animal species will also be adequately represented.
Amphibians[3]	12 (1 introduced)	
Reptiles[3]	8 (2 introduced)	
Freshwater Fish[3]	50 (20 introduced)	Present all or part of the year
Vascular Plants[4]	1249 (383 introduced)	Native

Table 5. Bird Population Changes in King County Over the Past 150 Years.

Non-native Birds Now Naturalized:	Native Birds Now More Abundant and/or Widespread Than 150 Years Ago:	Native Birds Now Less Abundant and/or Widespread Than 150 Years Ago:
Ring-necked Pheasant	Mallard	Northern Goshawk
Rock Pigeon	Gadwall	Marbled Murrelet
European Starling	Canada Goose*	Spotted Owl
House Sparrow	American Coot	Short-eared Owl
	Red-tailed Hawk	Hairy Woodpecker
American Birds Now Naturalized:	Killdeer	Western Meadowlark
	Green Heron	Olive-sided Flycatcher
California Quail	Caspian Tern	Purple Finch
	Glaucous-winged Gull	
	Glaucous-winged Gull x Western Gull Hybrid	**Native Birds Extirpated from Region:**
	Barred Owl	
	Anna's Hummingbird	Yellow-billed Cuckoo
	Cliff Swallow	
	American Crow	
	Western Scrub-Jay	
	American Robin	
	White-crowned Sparrow	
	Bullock's Oriole	
	Brewer's Blackbird	
	Brown-headed Cowbird	
	House Finch	
	Bewick's Wren	

*In addition to being more abundant, Canada Goose has always been a migrant, but it is now naturalized as a breeding species.

so likely other forces are also at work impacting their populations. Possible explanations include a reduction of prey as a result of pesticides and predation by gulls and American Crows.

Brown-headed Cowbirds have increased as a result of forest fragmentation, and their increase has caused declines in many other species of native birds because of their practice of nest parasitism. Some species, including Cedar Waxwings, American Robins, and jays actually recognize and eject cowbird eggs when they appear in their nests. They might instead build a new nest over the top of the old one with the cowbird egg. The Yellow Warbler and the Song Sparrow are the two most often parasitized species, though the Yellow Warbler is one species that may build a new nest on top of a nest with cowbird eggs.

Some species are on the increase because of range expansions. These species include the Western Scrub-Jay and Anna's Hummingbird, and both range expansions may be related to the presence of feeders as well as climate change. The increases in populations of species such as House Finches and Brewer's Blackbirds are also at least partially due to the presence of bird feeders.

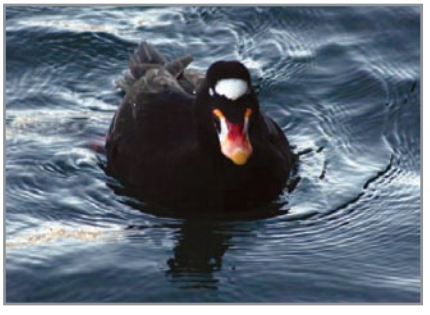
Fewer bird species are on the list of declining populations, and those species tend to have narrower habitat requirements and are associated with the forests that once blanketed the entire region. Spotted Owls and Marbled Murrelets require old-growth forest for breeding, and only a few remnant patches of old-growth remain in King County. The causes of some species' declines (Olive-sided Flycatcher, for example) is uncertain and may be related to loss of wintering habitat.

Some species are not on the list above because despite serious declines earlier in the century, they have come back to numbers similar to pre-settlement times. Such species include several of the raptors that were affected by DDT in mid-twentieth century, including Peregrine Falcons, Bald Eagles, and Osprey. After DDT was banned in 1972, these species have made a strong comeback. Peregrines were downlisted from "endangered" to "sensitive," and Bald Eagles have been moved from "endangered" to "threatened" status and are being considered for delisting.

Lewis' Woodpecker is one of several species that became fairly common in western Washington when areas were originally opened up for logging. These birds have been extirpated from the county as a breeding species as a result of development and fire suppression, along with the invasion of European Starlings. Western Bluebirds, Lazuli Buntings, Chipping Sparrows, and House Wrens similarly have experienced a boom and bust with the changing landscape; however, unlike Lewis' Woodpecker, each of these species still breeds in the county in very small numbers. Additionally, declines of some cavity-nesting species such as Western Bluebirds may be attributed to a combination of competition with non-native House Sparrows and European Starlings for nesting cavities, a reduction of natural cavities, and regional climactic changes that have resulted in reduced numbers of prey. House Wrens are reportedly declining in King County, despite increasing in most other parts of the state and country, and the reasons for their decline are likely similar to those of the Western Bluebird.

Purple Martin is a unique species because of its close association with humans. In King County, this species would be extirpated were it not for the presence of nesting gourds and boxes. Purple martins are cavity nesters, and the natural cavities they would use have either disappeared with development or are usurped by European Starlings and House Sparrows. They survive and thrive along marine shorelines of King County now because the gourds are hung above water, where the Starlings and House Sparrows apparently are less likely to nest, and because of the diligence of volunteers who closely monitor them and attempt to keep the non-natives from their nest boxes.

According to the Washington Ornithological Society, 221 breeding and non-breeding bird species are common, uncommon, or usually seen on an annual basis



Surf scoters are seabirds that overwinter in Puget Sound. Photo: Jennifer Vanderhoof.

Rough-winged swallows use riparian habitats found along streams, ponds, and rivers. Photo: Jennifer Vanderhoof.

in King County. We've already mentioned that 164 species breed in the county. Of those 164 species, 50 are here only during the spring and summer breeding months. Approximately 50 additional species over-winter in King County but migrate out of the county for the breeding season.

Some of the remaining species that are here year-round may migrate locally, depending on their life histories. For example, different individuals of the same species may move in and out of the county. Additionally, some species may remain in great concentrations in the county year round, whereas with other species most individuals migrate and only a very few remain behind.

The 50 or so species that are here only during the winter months are mostly waterfowl, marine birds, and gulls. All totaled, these 50 include 15 species of geese and ducks, 7 species of loons and grebes, 1 cormorant, 2 raptors (1 hawk and 1 falcon), 8 species of shorebirds, 9 species of gulls, 2 alcids, 1 shrike, and 4 species of sparrows.

The 50 or so species that are here only during breeding season come from a wider set of families than the winter-only birds. Most of these species are passerines and include, among others, 8 species of tyrant flycatchers, 6 species of swallows, and 8 species of warblers. Nearly all 50 species are Neotropical Migrants.

Among the species that remain year round in King County are 16 species of geese and ducks, 9 species of eagles, hawks, and falcons, 8 species of owls, 7 species of woodpecker, and 6 species of corvids. Additionally, 42 species of passerines are present year-round and include 3 species of chickadees, 3 species of wrens, 4 thrushes, 4 warblers, and 5 species of sparrows.

In addition to the 221 species expected to be seen annually in the county, another 36 are considered rare (with more than 5 records), and 117 species have been observed in the county fewer than 5 times on record. Often, the rare birds were more common before Euro-American settlement; whereas, most of the birds with fewer than 5 records have been accidental migrants and say little about the county's long-term biodiversity.

It is commonly recognized that birds are useful indicators of biodiversity in part because they are easiest of all the animal classes to observe. As is readily apparent in the table above, the last 150 years have witnessed an increase in bird species richness, as the landscape has been altered and new habitats have formed. Generalist species are able to take advantage of the increasing number of human-created habitats, and as such add considerably to biodiversity. Additionally, some of the unique habitat types that are required or preferred by birds, such as stream/riparian areas, are still present. Although many riparian areas have been altered significantly, many still remain vegetated adequately enough to provide nesting habitat, food, and cover required by many species of birds. Wetlands are another habitat type that are used by a relatively high number of animal species. And whereas some streams have been altered greatly but are still present, many wetlands have been drained and filled such that no wildlife function remains whatsoever. Animals that rely heavily or solely on wetlands for their survival and lack the mobility of birds have suffered dramatic declines in the past 150 years as a result of these wetland losses.

Mammals, reptiles, and amphibians are not as easily observable as birds, and as such, fewer studies on them are conducted and fewer statistics are known about them in King County. Nonetheless, some general trends have been established.

Mammals

Many large carnivores have declined throughout their range, including in King County. Grizzly bears and gray wolves are presumed extirpated. Mountain lions

and black bears are frequently and increasingly reported in rural residential environments as their natural habitat is lost to development. In addition to being squeezed out of their natural habitat, these species are drawn to the garbage and pet food people leave outside. Coyotes are a large carnivore that may continue to thrive, despite sub-optimal habitat conditions, so they are likely not declining in population. Bobcats also use a variety of habitat types and although their populations are likely lower than historic levels, like mountain lions, black bears, and coyotes, they are able to thrive in the natural habitats (and some non-natural) that remain.

Fishers, a forest carnivore historically hunted for its fur, are presumed extirpated, though it is possible some survive in extremely remote areas of the county. River otters, on the other hand, have made a come-back from over-hunting, and although they are nowhere near historic levels, they are thriving and possibly increasing. These otters may be found in rivers, streams, and lakes, as well as estuaries and large marine waterways of King County. Sea otters are a coastal species; they may visit King County's Puget Sound waters, but only very rarely, and they are not breeding here. Fishers and otters are members of the mustelid family; other members include the weasels, ermine, mink, and wolverine. Like the fisher, wolverines, another forest carnivore, are also presumed extirpated from the county. Mink, like river otters, are closely associated with water, but mink can use smaller rivers and wetlands. Mink are widespread; however, they are considered a species of local importance in King County, as are marten, another mustelid. Martens, an arboreal species that tends to be absent from cuts and burns, occur state-wide in mountainous areas. Highest densities of martens occur in Engelmann Spruce/Subalpine Fir forests greater than 100 years old and having a canopy cover exceeding 30 percent. Because of their narrow habitat requirements, they are not likely present in King County in high numbers or increasing populations; however, their status in the county is unknown.

Native raccoons and introduced Virginia opossums continue to expand their range throughout many suburban and even urban habitats. Raccoons and opossums are serious threats to birds because of their predation on songbird and waterbird eggs and chicks.

The non-native nutria, a large aquatic rodent, has increased and expanded dramatically throughout the Northwest, and they are now established in King County. At low densities, nutria are not thought to do much damage, but at higher densities, they compete with the native muskrat, damage native vegetation, reduce food and cover available to migratory birds and waterfowl, and reduce the quality of wetland habitat. Although their densities in King County are currently low, they are increasing and could become problematic over time. Beaver populations are dramatically reduced from historic levels as a result of trapping and urbanization of stream environments. However, in 2000 a ban on body-gripping traps was enacted in Washington, and since then beavers have been increasing in numbers. This increase in beavers has become an increasing problem for home owners (and wildlife biologists) in King County because beavers often cause flooding of residential areas. Beavers help form wetlands that (1) attract wide varieties of plant and animal species, (2) form excellent rearing habitat for some salmonid species, and (3) help reduce flash flooding at one extreme and dry stream beds at the other. Because their protection favors the preservation of a whole series of other plants and animals with similar habitat requirements, beavers are considered an umbrella species; because their loss often equates to the loss of entire ecosystems, they are also considered a keystone species. Because of the benefits

Black bear are large mammals found in forested environs. As humans have encroached on their habitat, they occasionally surprise rural landowners by showing up in their back yards. Photo: Kim Stark.

of beavers and the opposing flooding issues, the management of this species has become one of the biggest wildlife issues King County is currently facing.

Elk and Columbian black-tailed deer are both species of local importance in King County. Populations of both of these species shift when areas are opened up from logging (increase) and when canopy closure of regenerated stands occurs (decrease). Deer frequently forage in yards in rural areas and are thus considered pests by gardening landowners. Mountain goats are also considered a species of local importance. These are a high-elevation species that may get squeezed out of areas with trails and other human use.

House mice and black and Norway rats are a non-native invasive species that continue to expand their range as they follow humans to newly created suburbs and other residences in rural areas. These rodents are especially serious competitors and predators on native small mammals with the capability of totally extirpating native small mammals from wetlands and their buffers.

Non-native eastern gray squirrels have increased and expanded in population dramatically. This species mostly occupies urban environments, where it fills a newly created niche. Eastern fox squirrels were introduced in the early to mid-twentieth century, but have since disappeared from King County (though not from the Pacific Northwest). Douglas' squirrels, one of our native tree squirrels are declining because of urbanization.

Killer whales (Orcas) are the most common whale species seen in King County waters. The Southern Resident killer whales were federally listed as endangered in November 2005 because of population declines. There are currently about 84 whales in this population. The southern resident population is thought to feed solely on salmon, whose populations have declined from historic levels. The other primary threat to this population is reduced reproductive capacity and possibly declining health as a result of extremely high levels of pollutants found in their bodies.

Three other whale species are occasionally seen in King County waters: the gray whale, minke whale, and humpback whale. The gray whale eastern Pacific stock has increased in abundance from the 1800s and 1900s, when they were commercially hunted. Abundance was so low that the gray whale was federally listed as an endangered species in 1970. The population has increased to a sustainable level that led to its removal from the endangered species list in 1995. Gray whales are seen annually around Whidbey Island (just north of King County waters) and once every two years or so, one or two whales are seen in King County waters. There are no accurate population size numbers for the entire stock of North Pacific minke whales, but there may be between 600 and 1000 minke whales in California, Oregon, and Washington waters. Minke whales are not well documented in King County waters, but they are infrequently seen. Humpback whale are rarely seen in King County waters. The most recent occurrence was in 2006, and it was an injured animal.

Three species of pinnipeds (sea lions and seals) may be found in King County waters: California sea lion, Steller sea lion, and harbor seal. The California sea lions that use inland Puget Sound and King County waters are males from the California population that make seasonal migrations into Puget Sound. Estimates for the California population are over 200,000 animals but a much smaller number are seen in Puget Sound. Sightings in King County appear to be stable over the last several years. They are often seen (and heard) on floating buoys and anchored barges.

Steller sea lions (also called Northern sea lions) use haul-out areas on the Washington Coast, and a small number of individuals are observed in Puget Sound waters intermittently. They are occasionally seen in King County waters on certain jetties and piers, though they have never been documented in large numbers in the county.

The population of harbor seals was severely reduced in Washington in the first half of the 1900s. Their reduction was intentional: harbor seals were perceived as being in direct competition for salmon with commercial and sport salmon fishermen, so state control programs were put into place. After these control programs ended as a result of the Marine Mammal Protection Act of 1972, harbor seal populations have recovered to near historic levels with about 14,000 animals in inland Puget Sound,

including King County. They breed throughout their range, so breeding occurs in inland Puget Sound waters, and pupping occurs in King County as well as other parts of the Sound.

Amphibians and Reptiles

Amphibians have been on the earth for over 360 million years and, as a group, are now under global threat for multiple reasons, many of which may also account for their declining distributions and numbers in King County. The greatest threats to amphibians and reptiles in King County are habitat destruction and fragmentation, pesticides and herbicides, and the introduction of exotic species and their associated pathogens. Additionally, a recent concern has been raised regarding the pervasiveness and potential harmful effects of pharmaceuticals, especially hormones and anti-depressants and also personal care products, in aquatic systems.

Oregon spotted frogs are assumed to be extirpated in King County, and western toads have declined dramatically throughout the Puget Sound Lowlands. Northern red-legged frog and the coastal tailed frog have decreased throughout their historic range. Currently, coastal tailed frogs are found in higher elevation streams in the Cascades and foothills. Historically, Lewis Creek, a lowland tributary to Lake Washington, had coastal tailed frogs. Their known former presence there indicates two important things: (1) coastal tailed frogs were originally found from sea level to high elevation Cascade streams, and (2) their original range included the Puget Sound lowlands, where cities and unincorporated developed areas now dominate. Today, the silt in the headwaters of Lewis Creek is very deep and water temperatures during summer flows may be too warm, though the reasons for the tailed frogs' disappearance in this creek are unknown.

Pacific treefrogs are the most abundant frog in the Puget Sound region and are commonly heard calling in loud choruses in early spring. Photo: Jo Wilhelm.

Rough-skinned newts and other lentic- (pond) breeding salamanders in the county most likely also have declined with land clearing, agriculture, and development. Lotic- (stream) breeding species such as the Coastal Giant salamander may also have disappeared from historic ranges with increasing urbanization, forestry, and agriculture adjacent to creeks and streams. Forest practices most likely influence populations of western red-backed salamander, Ensatina, Larch mountain salamanders, and other terrestrial breeding species. Scientists believe that historically the Larch Mountain salamanders' range included the Cascade Mountains and possibly the foothills all the way to Snoqualmie Pass. It is an endemic species whose range has dramatically declined, resulting in two disjunct populations that may be genetically distinct. Consequently, studies of threats and protection measures are recommended to retain the unique biodiversity represented by this species.

Western Pond Turtles have become locally extinct and have disappeared from much of their former range. Several non-native turtle species have been introduced, and one of these, the red-eared slider, has increased dramatically. This species competes with native turtles for basking sites, nesting sites, and food. Snapping turtles are another example of an introduced species to King County that may thrive here unless controlled. They are our largest freshwater turtle, are omnivores and out-compete native species. Furthermore, they predate on other turtles, snakes, fish, large invertebrates (clams, snails, crayfish), and vegetation. Painted turtles, which were most likely introduced from east of the Cascades, are now widely distributed and appear to be thriving. In urban and most developed suburban areas, our most common reptiles, three species of garter snakes, are rarely seen although they may still be relatively common in rural and farm landscapes, especially when open areas are available in proximity to water.

The Inland Fishes of King County

In general, the inland (freshwater and brackish water) fish fauna of King County lakes, streams, and rivers is poor when compared to the faunas of Midwestern and Eastern aquatic habitats. The number of native inland fish species in King County is only about 30 and is divided among 10 families. Many non-native species have been added to this fauna, mostly to serve sport-fishing interests. Some were introduced by anglers, others by federal and state fishery agencies over the last century, some were probably accidental or inadvertent introductions. Some species, the American shad, for example, has made its way into King County waters from the original transplants made in the Sacramento River of California in 1871. At last count, approximately 20 (confirmed) non-native species currently reside in King County waters.

Salmonids

The native Salmonids—the Pacific salmon, char and whitefishes—are the most prominent fishes of King County waters, arguably the most prominent fishes of all Pacific Northwest freshwaters from California through Alaska. Eleven salmonid species occur in King County waters. Of this group, the species of Pacific salmon, members of the genus *Oncorhynchus*, are by far the most important and iconic. These fishes provided subsistence to Native Americans before white settlers arrived, and these fish became the basis for lucrative commercial fisheries late in the 19th Century throughout Puget Sound. They remain important components of both commercial and recreational fisheries today.

There are 7 species of the genus *Oncorhynchus* that inhabit King County waters: Chinook or king salmon, the largest and rarest of the group; chum or dog salmon; sockeye salmon, sometimes called blueback or red salmon; coho, or silver, salmon, the most widespread in King County; pink salmon, the smallest and most numerous; steelhead trout, a favorite of recreational anglers; and Coastal cutthroat trout, an inhabitant of even the smallest streams in the county. As reflected in the genus name, all of these species share common morphological and life history traits. Among the most prominent is an *anadromous* habit—the adults spawn in freshwater rivers and streams, their young migrate to the ocean after emerging from nests in the streambed, then after some variable period of from 1 to 6 years (depending on the species), they return to their natal streams to repeat the cycle. The first five species in the list above are also *semelparous*, that is, they die after a single spawning. The other species—steelhead and cutthroat—may spawn multiple times during their lives.

What salmonids lack in species richness (when compared to Cyprinids, for example), they more than compensate for in life history diversity. In the group as a whole there are four general breeding migration types: anadromy (explained above); adfluvial (spawn in rivers and streams but move to lakes to feed); fluvial (spawn in small streams and tributaries but move to large rivers to as adults); and resident (forms that remain in small streams all their lives). All these forms occur in the waters of the county. In addition, various migratory timings are evident. In Chinook, where this seasonal diversity is most well developed, some salmon "runs," or populations, enter freshwater as adults in the fall, just at the onset of the rainy season, whereas other runs enter in late spring, presumably catching the snowmelt runoff. A few populations enter in mid-summer and spawn in the autumn but in areas distinct from the fall run. King County has primarily fall runs although there is some evidence of a spring run—now extirpated—that used the upper Green River.

Each species has a preference for a slightly different portion of the river system for spawning and rearing. Chinook, for example, are very large fish (20 kilograms, 44 pounds, or more), so they tend to spawn in the wide

This coho has returned to its native stream to spawn and die. The white patches on its fins are signs of a long and taxing journey. Photo: Kollin Higgins.

and deep reaches of mainstem rivers, sometimes at depths of 6 meters (20 feet). Coho salmon, sometimes called the backyard salmon, tend to spawn in small streams that are often no more than 1+ meter (2 - 4 feet) wide. Other divergent traits are time of out-migration of juveniles and the choice of rearing habitats. Chum salmon, for example, tend to migrate quickly to saltwater after emerging, whereas steelhead may remain in small streams for 2 - 3 years before migrating. Sockeye salmon have a non-anadromous form called kokanee that occurs in Lake Washington, Lake Sammamish, and Lake Sawyer. Kokanee live in these lakes and migrate into tributaries for spawning.

The two native char species (genus *Salvelinus*), Dolly Varden and the bull trout, form a complex that is difficult to separate by simple observation. Alike in shape and form, as well as life history and habit, these fishes cannot be clearly delineated in Washington. Both species probably occur in King County waters although bull trout is probably more widespread; Dolly Varden's southern distribution in Puget Sound is the Lake Washington drainage. Bull trout and Dolly Varden use the Skykomish River in northeast King County, and an isolated population of bull trout occurs in the Cedar and Rex rivers above Chester Morse Lake in the City of Seattle's protected municipal watershed.

The other native salmonids in King County are two species of whitefish from the genus *Coregonus*: the mountain whitefish, which tends to be relatively widespread, and the pygmy whitefish, the rarest salmonid in King County. Pygmy whitefish occurs as relict populations in Washington, Idaho, and British Columbia but is known from only one location in King County, Chester Morse Lake in the Cedar River watershed.

Three non-native species of salmonid occur in King County, as well: brook trout, brown trout, and Atlantic salmon. Brook trout is an eastern species of char that is a favorite of fly fishermen and has been widely introduced in many streams of upland King County (above barriers to anadromous fishes) and in many naturally fishless alpine lakes. The first brook trout were probably introduced late in the 19th Century. Brook trout have been implicated in the decline of cutthroat trout where these species overlap and in the decline of amphibians in alpine lakes. Brown trout is a European species first introduced to Green Lake in Seattle in the early 1900s. The species is now present in Lake Washington and Lake Sammamish as well. Atlantic salmon were first introduced to Puget Sound waters as escapees from commercial net-farming pens and were first observed in local rivers in 1996. By 2000, Atlantic salmon had been observed moving through the Ballard Locks into Lake Washington and into the Cedar River; several hundred adults were seen in the middle reaches of the Green River at about the same time. These adults were most likely escapees from net pens as no juveniles from natural reproduction had been collected from our streams as of 2003. However, successful reproduction of escaped Atlantic salmon has been documented in Vancouver Island, Canada, streams only a few hundred miles to the north.

Two other salmonids, the Lake Whitefish (genus *Coregonus*) and the Lake Trout (genus *Salvelinus*), were planted in Lake Washington late in the 19th Century but have apparently failed to persist there.

Status of Salmonids in King County

In general, over the last century, the native salmonids of King County have declined in abundance, distribution, and diversity throughout County waters. The possible exceptions are pink salmon and sockeye salmon. Once rare in the Lake Washington system, the sockeye salmon population in the lake has increased dramatically since the late 1960s and has reached upwards of 400,000 returning adults in many years since. Although it is believed that sockeye were native to the Lake Washington system, their numbers were quite low until stocking began in the late 1930s using fish from Baker Lake to the north. Even so, abundance did not increase quickly and little attention was given to the species until their numbers rose dramatically in the 1970s and 1980s. In many years since, the run has supported a popular recreation and Tribal fishery in the heart of the urban environment.

Pink salmon, once present mainly in the Snoqualmie River, have recently been observed in great numbers in the Green River as well. The reasons for this presence and increase in abundance are unclear at this time. In

the winter of 2007, pink salmon numbers in the Green River exceeded one million during their upstream migration, truly an amazing spectacle.

Several other salmonid species have experienced serious declines in abundance or range for reasons that include habitat degradation from forestry, agriculture, and urban development; high harvest rates on commercially valuable species; and reliance on artificial propagation programs. A more serious effect of these declines may be the loss of diversity—genetic and life history—in a group of animals whose hallmark is the ability for local adaptation to watershed conditions. In most salmon species, this diversity has historically manifested as multiple local populations, often multiple populations, within a river system. In Chinook salmon, for example, the prevailing scientific information suggests that fully a third of the historic populations of the Puget Sound have been extirpated (approximately 15 populations) leaving 22 extant populations. Most of these populations were of the spring run type, and only a handful remain.

In 1998, bull trout were listed as Threatened under the US Endangered Species Act (ESA), and efforts are underway to recover that species throughout its historic range in Puget Sound. Soon after, in 1999, Chinook salmon were listed as Threatened also. Led by local officials and Tribes, a massive voluntary effort was begun to develop a recovery plan that would satisfy the requirements of the ESA and result in the recovery of Chinook salmon throughout Puget Sound. This effort, called the Shared Strategy for Puget Sound, produced a recovery plan in 2006; that plan was formally accepted by the Federal government in February of 2007. Most recently, steelhead trout—a member of the salmon genus and not a true trout—has been listed under the ESA as well.

Bull trout, a listed threatened species, require cold, clean waters often found in streams of King County's foothills and mountains. Photo: Hans Berge.

Other Native Freshwater Fishes of King County

Besides the salmonids, nineteen other species of fishes are native to King County waters. This includes the Western brook lamprey, a stream-dwelling, diminutive cousin of the larger Pacific lamprey, but no threat to native salmon; white sturgeon, the largest native fish in King County waters and only rarely observed in Lake Washington; longfin smelt; six members of the family Cyprinidae (minnows), including three species of dace, one species of shiner, a peamouth chub, and the northern pikeminnow; two species of sucker (one, the largescale is often mistaken for a salmonid because of its upstream migratory habit); the ubiquitous threespine stickleback; six species of sculpin; and the starry flounder, a flatfish of brackish river mouths.

Non-native Freshwater Fishes of King County

Besides the three introduced salmonids species, at least 17 other species of non-native fishes have been introduced to King County waters. One of these, the Olympic mudminnow, is a native to the Olympic Mountain drainages of Washington and was introduced to a few King County ponds in the 1970s. Though it is a state native, it is still considered to be non-native to our local waters.

The remaining 16 non-native species comprise 7 families; of these, the sunfishes are well represented by 7 species. This family includes fishes translocated from warm water lakes of the Midwest and eastern side of the state of Washington: rock bass, confined to two small lakes in the county, smallmouth and largemouth bass, bluegill, pumpkinseed, warmouth, and black crappie. These species, especially the basses, are favorites of many anglers and some of the species were probably introduced by fishermen. Others were stocked by federal and state fishery agencies to provide fishing opportunities for citizens.

One species of herring, the American shad, was planted in the Sacramento River in 1871; by 1876, the species was found in the Columbia River. It is believed that the entire Northwest coast population is a result of that single introduction that migrated progressively northward.

Three species of Cyprinids (minnows) also occur in our waters: goldfish, common carp, and tench. Goldfish are probably escapes from backyard ponds or even from home aquaria—this species is common in many ponds and small lakes of the lowlands. Common carp are found in Lake Washington and Lake Sammamish as well as other lowland lakes. Tench are a rare species that occurs in Lake Washington as a result of the release of several individuals that were displayed at the Alaska-Yukon Exposition in Seattle in 1909.

Two species of catfishes (Ictalurids) are present: brown bullhead is widespread and common in several King County lakes; channel catfish, first stocked in Washington waters in 1892, are uncommon in King County. In 1976, a channel catfish weighing 2 kilograms (4.5 pounds) was taken from Lake Washington; the capture of this specimen suggests that some individuals were thriving prior to 1982, when the stocking of channel catfish began in earnest. They have now been stocked into a number of Washington lakes to prey on abundant forage fish such as stunted yellow perch, and to provide another gamefish for anglers. Their presence in other King County lakes is unknown.

Yellow perch is an introduced species and is common in Lake Washington and Lake Sammamish as well as other large lakes in King County. It was introduced in the 1890s to a few small lakes in the area and spread via streams and anglers to become common. In 1999, yellow perch was thought to be one of the most abundant fishes in Lake Washington.

In the nearshore waters of King County, striped bass, some grown to a large size, are occasionally encountered by saltwater anglers. This species is relatively scarce in Puget Sound waters although its range reaches north to southern Vancouver Island. In 1968, a 17 kilogram (37 pound) specimen was taken near Everett, Washington, just a few miles to the north of Seattle.

The most exotic non-native fish encountered in King County waters is probably the Oriental weatherfish, a species of loach that is probably an escape from home aquaria. The oriental weatherfish was first reported in King County in 1997, from Union Bay, a freshwater lake between the Sound and Lake Washington. A second specimen was reported from a tributary to Lake Washington in 1998 and, in 1999, an established population was reported from Portage Bay, a small embayment of Lake Washington. Twenty-one fish were removed at that time and an additional 15 were observed. Thus far, only this single population has been confirmed.

The lowland lakes of King County possess relatively benign environmental conditions; they rarely freeze, and then only thinly and for a few days at most. While these conditions do not necessarily favor the rapid reproduction and growth of warmwater fishes, there is little to discourage invaders in species-poor waters. If the predictions of global climate change are realized and lake and stream temperatures rise, even to the lower level scenarios, these exotic fishes may find the conditions more to their liking than do the native, coldwater fishes.

Marine Fish

Puget Sound supports over 200 species of marine fishes, many of which depend upon the productivity and critical habitat attributes found in the marine nearshore ecosystem. Fish surveys in the shallow intertidal areas in 2001 and 2002 showed that at least 60 of these species occur within the shallow intertidal areas of King County. This environment is especially important for juvenile life history stages of anadromous salmonids. Chinook and Chum salmon juveniles rely on this habitat more than other juvenile salmonids species. Subadult and adult cutthroat trout and bull trout also rely on this area for various parts of the year. Sea-run cutthroat trout are found throughout the marine shorelines of King County, while bull trout have been found in far fewer numbers and mostly in the northern half of the county.

Of particular importance to the larger Puget Sound food web (especially marine mammals, sea birds, and salmonids) are three species of forage fish—sand lance, surf smelt and herring. The Quartermaster herring stock

is the only known spawning stock within King County. Spawning only occurs along the protected shorelines between Vashon and Maury Islands, within the Maury Island Environmental Aquatic Reserve. This stock was fished heavily in the past, but appears to be stable and healthy. Both sand lance and surf smelt are found primarily within the southern half of King County, likely due to the substantial filling of their spawning habitats in the northern half of the County by a railroad along the intertidal zone.

1.4 THREATS TO BIODIVERSITY

Throughout the world, biodiversity is threatened by the effects of increasing human populations, and King County is no different. The greatest threats in King County are urbanization and residential development, and invasive plant and animal species. Global climate change is also recognized as a major threat to biodiversity and its effects are beginning to be observed in the county, although its full impacts are only beginning to be understood and are presumed to increase over time. Diseases are also a threat that primarily affects native vegetation. Finally, pollution threatens some species, particularly marine species. The county has experienced and continues to experience the alteration of genetic and species diversity that reflect the destruction of natural habitats and alterations to the landscape (see Section 1.3).

Development

King County is the most populous county in Washington State, and it has seen nearly all of its native landscape altered during the last 150 years. Vast areas of the county have been converted to human uses, particularly in the Puget Lowland, Eastern Puget Riverine Lowland, and Eastern Puget Uplands ecoregions (see Landscape Diversity Map). Activities such as forestry, agriculture, and urbanization have reduced and often eliminated the connectivity of native vegetation in King County and transformed the original composition and arrangement of the landscape to alternative structures and functions.

The transformation of the landscape has had negative impacts on many native wildlife species in King County (also see Section 1.3). Vertebrate and invertebrate wildlife species have experienced native habitat loss and alteration, interrupted migration patterns, displacement, reduced reproductive success, and exposure to invading species and predators. As the county's landscape has become fragmented and vegetated habitats have shrunk, animals populations have been split and isolated. In many instances the landscape is no longer capable of supporting populations large enough to maintain themselves; many are locally extirpated even though some attributes of the habitat remains. Examples of this can be seen in the grizzly and gray wolf populations. When forest patches become more fragmented, their edge to area ratio increases and they become more susceptible to penetration by predators, (including nest predators) and parasites. Non-native invasive animal species continue to be a growing threat in King County, as more are introduced over time. For further discussion of these animals, see section 1.3.

Development also carries with it threats from pollution of various kinds. Fishes and marine mammals seem to be particularly susceptible and have been shown to bioaccumulate various pollutants. Additionally, toxic contaminants from man-made sources threaten Puget Sound health. These contaminants include chemicals used for industrial, consumer, and agricultural purposes, transportation-related chemicals, and byproducts from manufacturing and combustion of fossil fuels. For

Scots broom is a highly invasive non-native plant that can take over large areas of land, as evidenced in this aerial photo by all the yellow that is visible.

example, harbor seals (*Phoca vitulina*) and killer whales (*Orcinus orca*) carry large concentrations of polychlorinated biphenyl (PCBs) compounds and increasingly greater concentrations of flame retardant chemicals in their fatty tissue. The effects of these chemical loads are not well known, but in the case of killer whales, the contaminants can weaken immune systems, cause reproductive failure, and lower the survival rate of calves through maternal transfer of contaminants.

Shoreline armoring, another aspect of development, leads to a loss of marine habitat and interferes with sediment transport processes. Throughout Puget Sound, armoring has led to a decline in forage fish spawning habitat, feeding habitat for marine birds, and total area and abundance of marine plants.

Invasive Species

The fragmentation and dissection of the county's native landscape is conducive to the invasion of non-native plant and animal species that have been accidentally or intentionally introduced and for the rapid invasion and colonization of newly disturbed habitats by some native species. Although the label "invasive" is most often attached to non-native species, native species may become invasive if the right environmental circumstances are present. In either case, our remaining native habitats are at considerable risk from invaders and are likely to become increasingly susceptible as climate change proceeds. A recent publication, *Invasive Species in the Pacific Northwest*, profiles a large number of plants and animals that are invasive to the Pacific Northwest, including King County. The authors have not included all non-native species that have been introduced to the area—agricultural and horticultural pests are not included, nor are some species that have been part of our landscape for so long that we have accepted them and consider them "naturalized." Nevertheless, the list is long and growing and the authors raise important questions about their effects on native ecosystems.

Invasive species are typically non-native plants or animals that are highly competitive, often difficult to control or eliminate, and, in extreme cases, may be quite destructive of native ecosystems or economically valuable plant and animal resources. Invasive plants that are highly destructive are termed "noxious weeds," whereas destructive invasive animals are classified as "pests." According to Washington's noxious weed law, public and private landowners are responsible for controlling and preventing the spread of certain specified noxious weeds on their property.

Japanese knotweed is a highly invasisve non-native plant that can grow vegetatively. Here a beaver has used some to help form its dam, and it is sprouting new plants. Photo: Jennifer Vanderhoof.

In King County alone, there are over 100 noxious weeds that have been identified by the King County Noxious Weed Control Board. Many of these species are so widespread that control and eradication is virtually impossible; eradication for these species is recommended but not required. One such species is Eurasian watermilfoil (*Myriophyllum spicatum*), an aquatic plant found in lakes, ponds, reservoirs, rivers, and streams. This species dramatically alters the ecology of a water body because it rapidly reproduces and forms dense mats that choke out native plants and animals. The distribution of watermilfoil now closely follows Interstate 5, the north-south running interstate highway in King County, and it has probably been spread from lake to lake on boat trailers. Other examples of noxious weeds that are so widespread in King County that eradicating them is nearly impossible are yellow flag iris (*Iris pseudacorus*), reed canarygrass (*Phalaris arundinacea*), Scot's broom (*Cytisus scoparius*), Himalayan and evergreen blackberry (*Rubus armeniacus* and *R. laciniatus*), English and Irish ivy (*Hedera helix* and *Hedera hibernica*), and purple loosestrife (*Lythrum salicaria*). Many of these species create monocultures and have probably decreased habitat biodiversity in King County significantly (see Section 1.3).

The marine environment is also host to numerous non-native species. Over 40 non-native species of plants and animals have been found in Puget Sound and many of those in King County. Non-native species may be introduced through ballast water discharges, transport on ships' hulls, importation of aquaculture species, and importation in live seafood shipments. Japanese eelgrass (*Zostera japonica*) is a non-native invasive marine plant found in scattered clumps or extensive meadows high on intertidal mud or sand flats. The full impacts of Japanese eelgrass on native eelgrass is still being debated, but it is clear that this colonizing species alters habitat structure, changes water flow and sediment deposition, and makes sediments finer and organic content richer. In King County, the non-native marine plant *Sargassum* is found along much of the shoreline, particularly along the West Seattle shoreline.

In the animal kingdom, invasive species are often no less harmful and are equally difficult to eradicate. This is particularly true for aquatic and marine species; many of these invasive organisms have proven difficult to detect in time to avoid serious or widespread outbreaks. In King County, little is known about the ecological effects of invasive animals but recent discoveries, coupled with concern about the effects of global climate change, lend an air of urgency to investigations into the extent of the invasive problem. A few species of concern in King County are the European Green Crab, the Asian mudsnail, the gypsy moth, American bullfrog, common carp, the brook trout in historically fishless alpine lakes, Atlantic salmon, European starling, eastern gray squirrel, and the nutria—a large aquatic rodent. A non-native tunicate was recently found in the marine waters of King County. Tunicates are a type of invertebrate that can spread rapidly, and non-natives can crowd out or kill populations of local native marine species.

Disease

Native plant communities and species are also threatened by disease. Some diseases that are of particular concern in King County include dogwood anthracnose (*Discula destructiva*) and white pine blister rust. In the case of dogwood anthracnose, this fungus affects the Eastern Dogwood, the ornamental Japanese dogwood, and the native Pacific dogwood, which is found along forest edges, streams, and riverbanks. Stressed dogwoods found in moist, shaded environments are more susceptible, particularly those in urban areas. Although it is considered predominately an urban problem, it has been spreading into natural environments. It causes the dogwood leaves to turn brown and fall off prematurely; it also causes cankers on the branches and trunks. Eventually, the tree is strangled within 1 - 3 years of infection because vascular tissue becomes constricted and water and nutrient flow is impeded. The fungus is thought to have arrived in the Pacific Northwest (PNW) with shipments of Japanese dogwood to the area in the late 1960s. Another disease of concern is white pine blister rust, which has devastated much of the white pine in the Pacific Northwest. This blister rust has mainly been observed in a few isolated locations of Western white pine in the lowlands and in the groves that sit at the lower elevations of the foothills, especially in the southeast part of the county. It is uncertain how serious a problem it currently is, but it may increase with warming. In the PNW, the infection began at a nursery in Vancouver, British Columbia, Canada in 1910 and spread rapidly south to Washington and Idaho by 1923. The origin of the disease was traced to the importation of infected Eastern White Pine seedlings from Europe in the early 1700s.

The impacts of these diseases can be substantial to wildlife. White pine forests provide an important food source for squirrels that eat their seeds, and Pacific dogwood provides food and shelter to many bird species and mammals. Recently in the Pacific Northwest, Pacific madrone trees and stands have been observed dying from an invading fungus of unknown origin. It is uncertain at this time if King County's few madrone stands will be similarly affected. These Madrona groves typically grow on dry, sandy and exposed sites and provide winter food (berries) for birds and other wildlife.

A disease of concern for some animals and humans, alike, is West Nile Virus. The disease appeared in North America for the first time in 1999 and appeared in King County in 2006. Thus far six cases in birds and a single case in a horse have been confirmed; no human cases have been confirmed. This virus, transmitted by mosquitoes, can cause swelling of the brain and inflammation of the membrane surrounding the brain. So far,

138 species of birds in the United States are known to be infected; Native crows, ravens and jays are particularly susceptible to the virus.

Climate Change

The American Pacific Northwest may experience slightly less dramatic effects from climate change than the subarctic and arctic areas of the continent. Nevertheless, the effect on native biodiversity is likely to be serious and somewhat unpredictable. In King County, some effects already are apparent as average temperatures over the last decade have increased slowly but steadily, especially in winter. For many of our native species, climate change will be an added stress to ecosystems and populations. The following effects are predicted to affect biodiversity in King County:

- Increases in direct mortality as a result of thermal stress: For many freshwater species, especially the salmonids and the freshwater mollusks, warming stream and lake temperatures may impose an added physiological burden that increases direct mortality. Already, adult salmonids on their spawning runs upstream have encountered water temperatures warm enough to halt their migrations for a time.
- Increases in productivity due to altered environmental regimes: As temperatures warm, some ecosystems such as lakes and wetlands may experience increases in primary productivity that will alter the species composition of plants and animals.
- Altered growth rates: Temperature is often considered a "master variable" in that it controls much of the physiological response of animals, especially cold-blooded animals such as salmon. Warmer water temperatures during incubation will likely increase the rates of development of embryos and juveniles and could alter the timing of emergence and out-migration from natal rivers. If nearshore productivity is not synchronous with this migration, juvenile salmon face a lack of food supply during a critical time of their early life history.
- Altered local distributions: Warming stream temperatures over the last decades may have already altered local distributions of certain of our cold-water species of salmon and char. Some early evidence suggests that local spawning patterns of steelhead and bull trout may be shifting upward (to higher elevations) in watersheds where these species are found. Other species that may be susceptible to this effect are freshwater mollusks of the genera *Margaritifera* and *Anodonta*. The same effect is likely for some alpine species of plants and animals that may experience conditions that drive an upward shift in distribution. Some species may find that such a shift is impossible since they occupy the highest zones in the county already.
- Regional range shifts: This effect is a significant issue for certain species that are at the southern limit of their ranges. In particular, sockeye salmon in the Lake Washington system may be at risk as ocean temperatures rise and the thermal refugia in the northeastern Pacific are pushed northward. This could cause a collapse of the sockeye's range northward some 1000 kilometers. The same shift might be observed for certain marine species such as the green sea urchin (*Strongylocentrotus droebachiensis*), which may be a useful sentinel species for the effects of warming on the intertidal habitats of King County.
- Biological invasions: This effect is a concern among ecologists insofar as several groups of animals and plants are highly mobile and can reproduce quite quickly if conditions permit. There is some evidence that many of the exotic marine fishes that have been observed with more frequency off Washington's coast and in the Strait of Juan de Fuca are likely candidates to move into Puget Sound as warming progresses. Many of the invasive freshwater fishes in King County are warmwater fishes and are likely to increase in abundance and distribution as lakes and streams warm.
- Phenological changes (altered timing of life history events such as migration and breeding): Because the migrations and breeding of most animal species are keyed to seasonal signals of light and temperature, changes in these patterns may be expected in the county as elsewhere. This effect will be critical for salmon and trout, whose migratory patterns, breeding times, and emer-

gence and out-migrations are keyed to river flow and temperature. If these environmental cues are temporally displaced, the life history patterns of many species will respond accordingly, and the direction of this response may not assure the survival of the species.

- Food web disruptions: This effect has already been observed in Lake Washington as a decoupling of certain parts of the phytoplankton-zooplankton food web, and it seems reasonable to believe that such food web effects are taking place in other county lakes as well. The cascading effects are not well-predicted, however, and will take some time to manifest in higher levels (salmon, for example) of the food web. The possibility of this effect in King County's marine ecosystem is of great concern.

1.5 BIODIVERSITY MANAGEMENT

King County has two general goals for biodiversity: (1) Protection of existing elements of biodiversity, and (2) the restoration and recovery of elements that have been unduly harmed by human interference. The accomplishment of those goals depends on multiple approaches, which are discussed in this section. Knowing whether the approaches are successful is crucial, and that is why monitoring is important and discussed at the end of this section.

With one exception, King County's biodiversity goals tend to be developed from the County's own perspective and have not been consciously embedded in regional or national biodiversity goals. The exception is the Shared Strategy for Puget Sound, the multi-jurisdictional collaboration to conserve Chinook salmon. This program has developed the explicit population and habitat goals necessary to recover Chinook salmon to sustainable population levels. Otherwise, there are few explicit biodiversity goals at the regional level that have wide acceptance, and biodiversity goals at the national level are generally non-existent, except on federal lands. The State of Washington, through its Natural Heritage Program, has developed some habitat-specific goals, but even these are often not explicit, nor do they hold any regulatory power. If there are large-scale biodiversity goals that are intended to be inclusive of any part of King County, they have been generated by non-governmental organizations such as The Nature Conservancy and may be at a scale of little direct relevance to King County.

In 2002 Washington became one of only a few states to articulate a state policy on biodiversity. In 2004, the Washington Biodiversity Council was established by the Governor to develop a 30-year vision for the conservation of the state's biodiversity. Conservation is to be accomplished through local, incentive-based programs on both private and public lands. In late 2004, a new Biodiversity Council was appointed by the Governor to develop a 30-year strategy to protect the full range of Washington's biodiversity. The new Council, which will expire in 2007, includes participation by the Washington Department of Fish and Wildlife, other public agencies, and private stakeholder groups. It is unclear however, if specific goals and objectives have been developed that apply to King County. It is also unclear how King County government should interact with this effort. Ideally, the county's biodiversity goals will nest within the larger regional goals of the State's effort thereby assuring continuity of biodiversity protection.

Protection of Existing Elements

The County protects elements of biodiversity in two basic ways: regulatory tools and direct protection through ownership and non-regulatory programs. There are four regulatory tools: the zoning codes that establish acceptable land uses and three complementary development ordinances.

The County zoning code is a potentially useful management tool for biodiversity protection although it has been used only weakly for that purpose. The establishment of land uses that are compatible with the protection and recovery of biodiversity could be made more explicit but the current zoning still has some clear benefits for biodiversity. This benefit is a result of the gradual thinning of development intensity as one travels from the urban lowlands eastward toward the Cascade foothills. The gradient of development intensity generally declines eastward, and native habitats remain in a land cover setting that is more conducive to their function.

King County's regulatory framework includes the Critical Areas Ordinance, Stormwater Ordinance, and Clearing and Grading Ordinance. The Critical Areas Ordinance (CAO) protects wetlands through buffers based on wildlife functions and local land use context, with maximum buffers of 91m on wetlands with high wildlife value and high land use intensity. Wetland Complexes were defined and protections were established to partially address habitat fragmentation in the developing landscape. The complexes group wetlands within 152 meters (500 feet) of each other that have no barriers to dispersal, and increase the number required to constitute a complex as quality (category) decreases. The Wildlife Habitat Network (see Landscape Diversity Map) was also designed to help reduce the effects of fragmentation by linking diverse habitats through the developed and developing landscape. The network is intended to facilitate animal dispersal by connecting isolated critical areas, segments, open space, and wooded areas on adjacent properties with a width of 91 meters (300 feet) but not less than 46 meters (150 feet) of protected land. The corridors tend to follow riparian and stream corridors across the lowlands and the upland plateau to the east and southeast of Lake Washington into the foothills. The Wildlife Habitat Network is enforced when a development proposal is received for a property that has a portion of the network running through it.

Unavoidable mitigation is addressed in the CAO through buffer-averaging, rural stewardship planning, mitigation banking, and mitigation reserves. Buffer averaging maintains total fixed-buffer area by allowing decreasing widths with wider compensating sections. Rural Stewardship Plans include site-specific habitat plans allowing buffer reductions if an increase in habitat can be achieved (see Restoration and Recovery below). Mitigation Banking protects wetlands in perpetuity in advance of authorized impacts. The Mitigation Reserves Program purchases and enhances, restores, maintains, or protects wetlands.

The Stormwater Ordinance prevents hydrological and water quality impacts to wetlands and streams with the highest flow protection levels matching the pre-developed site's peak discharge rates for the two-year and 10-year return periods, and includes pollution controls based on best management practices.

Significant to protecting wetlands and wildlife, the Clearing and Grading Ordinance places limits on clearing, and these limits get stricter as the lot acreage increases. In other words, as lot size increases, the relative percentage of allowable clearing declines. At a lot size of 2 hectares (5 acres) or greater, no more than 35 percent of the lot can be cleared. The choice and location for clearing, however, lies with the landowner, who must avoid clearing in critical areas (as per the CAO). If avoiding clearing in critical areas is not possible, the landowner must file for an alterations exception or write a Rural Stewardship Plan (see section 4.2). Landowners are sometimes encouraged to link uncleared areas on one lot with those of another; however, because most landowners wish to maximize privacy, most of them tend to carve out a space in the center of their properties.

Additional mechanisms used by the County for biodiversity protection involve ownership of lands or development rights, conservation easements, and a tax incentive program. These four mechanisms result in the protection of ecological lands and important features on privately owned lands:

- The County uses fee-simple acquisition in those cases where confident control of the feature is desirable. The County purchases the land outright, receiving clear title to the parcel. The County's ecological lands are in this category. The current inventory is 80 properties for a total of over 2,430 hectares (6,000 acres).
- The County may purchase the development rights to a parcel of land. This method allows the underlying current use to continue. The County has used this approach for the protection of farmlands and working forests. Currently, the County owns the development rights to 38,000 hectares (94,000 acres) of land.
- Conservation easements are most often used by the state and by private conservation organizations but have been useful to the County as well. With this tool, the County buys a conservation interest in a parcel of land but title remains with the landowner. There are 1,200 hectares (3,000 acres) of lands in conservation easements at present.

- The Public Benefit Rating System is a program that provides landowners with a substantial tax benefit for placing their lands in an open space category. At present, 720 landowners are participating in the program, and their lands account for 2,682 hectares (6,828 acres).
- As land develops in the County, especially residential lands, King County often seeks to maintain open space lands within subdivisions to act as corridors and habitat patches. Prior to the 1990s, this protection was accomplished through the environmental review process and a negotiation with the developer (based on the KC Open Space ordinances) to retain some parcels within the development as green space. The lands were placed in a separate parcel and designated as open space or sensitive land tracts and could not be developed. The lands were not public open space, however, but were owned either by the association or by some entity associated with the development. Today, similar open space lands are established at the time of development through multiple processes. One of these, the "4:1 process," specifies that developments in particular watersheds of the County must set aside 1.6 hectares (4 acres) of open space for every acre developed. The County does not have the ability to choose in which areas of the development the open space lands will occur although guidelines are often provided to influence the location.

Restoration and Recovery

The restoration of habitats is a crucial aspect of biodiversity management in King County, most especially for the recovery of Pacific salmon, but the approach is being applied increasingly to County-owned forest habitats and to wetlands.

Restoration work is mainly focused on streams and rivers for the benefit of salmon and salmon recovery. It is slowly expanding to take in other aquatic habitats and also to include terrestrial habitats—especially County-managed forest lands. The first restoration program began in the late 1980s as a small program focused on urban and suburban stream restoration, but it quickly expanded to include any stream in the unincorporated county. Cooperative programs were implemented with several cities and other agencies to expand the program in the early 1990s. In the last decade, the program has grown to a multi-million dollar effort with a section in the Department of Natural Resources and Parks devoted just to stream and river restoration. This section now provides its expertise to other departments—most notably Transportation—and even to other jurisdictions. Its expertise has grown markedly over the decade.

King County placed large woody debris in this stream in Meridian Valley to improve salmon/wildlife habitat.

King County's Forestry Program has also begun to use management techniques that have forest biodiversity as a major goal. These techniques are increasingly applied to the County's holdings of working forest lands and to private forest lands where the County provides advice through Forest Management Plans.

A third program just underway is the Rural Stewardship Program (RSP, see the description under section 2.2). This program encourages landowners to develop a land management plan in exchange for regulatory relief from some provisions of the Critical Areas Ordinance. The program requires the landowner, in discussion with King County stewards and scientists, to evaluate the property, the surrounding landscape, and the development proposal in a manner that derives an acceptable development plan and appropriate management practices for the land. Because most development proposals are carried out on "damaged" landscapes, the provisions of an RSP plan may actually improve some ecological functions.

Monitoring

King County has developed a program to measure the status and attainment of a set of environmental benchmarks. This program, called KingStats, is designed to measure both the relative status of several environmental indicators and the success of County programs at attaining its environmental goals. The program is being implemented and used quite successfully for water quality and some biological attributes such as macroinvertebrate (aquatic insects) indices, but it lacks both the data and the appropriate indicators to evaluate overall county biodiversity. Further work is underway to establish appropriate indicators for species, habitats, and ecosystems, and to develop methods to monitor and evaluate them at the very large scale of the county.

For now, the County relies on data supplied by other agencies to evaluate elements of biodiversity. This will probably change rapidly under the auspices of the County's Climate Change Initiative, however. In that initiative, an analysis of the sensitivity of King County's Biodiversity to predicted climate impacts is called for, along with the development of several indicators to act as "sentinels" and "umbrellas" to detect and evaluate the effects of climate change on biodiversity. These indicators will probably be developed at all levels of biodiversity from landscape to genetic so that we might better understand and predict local and regional effects.